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he Second National Water Assessment by the U.S. Water Resources Council

Part III Functional Water Uses

April 1978

U.S. Water Resources Council 2120 L Street, N.W. Washington, D.C. 20037

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PART III

FUNCTIONAL WATER USES

FOREWORD

The United States Water Resources Council was established by the Water Resources Planning Act of 1965 (P.L. 89-80) to maintain a continuing study and issue periodic reports on the Nation's water resources and their ability to meet present and future requirements. The results of the First National Water Assessment were issued by the Council in 1968 in The Nation's Water Resources. The First Assessment placed in a national perspective the estimates of present and future water and related land supplies and requirements of the Nation's water resources regions.

The Council initiated the Second National Water Assessment in October of 1974. In the analysis of the data the base year is 1975 and projections are made for 1985 and 2000. The United States has 21 water resources regions which for the purposes of the Second National Water Assessment were divided into 106 subregions. Comprehensive data and information were developed for each subregion. The subregion concept is to have one basin or a group of basins for which data could be collected and compiled.

Data collection and development of information for this report were conducted in three major phases: Phase One, Nationwide Analysis; Phase Two, Specific Problem Analysis; and, Phase Three, National Problems Analysis.

The Nationwide Analysis was conducted by Council member agencies and reflects their view of existing and future water requirements, the nature of problems, conflicts associated with efforts to meet the requirements, and implications for the future.

The Specific Problem Analysis was conducted on behalf of the Council by a regional entity in each of the 21 water resources regions. Each entity was comprised of a study team of representatives from state and Federal agencies. The Specific Problem Analysis viewed resource conditions and problems from a state-regional perspective.

The National Problems Analysis used the results of Phases One and Two to assess national problems for presentation in this report. The format is to present an overview of water resource management problems at the national, regional, and subregional level of detail.

An important feature of the Second National Water Assessment is that it presents a general "water balance" analysis for each of the 106 subregions. In these analyses the location and scope of critical water quantity, quality, and related land problems are indicated, as well as basic information needed for water and land management policies and programs.

The Nation's Water Resources, the final report of the Second National Water Assessment, is based on many reports and special studies. The Nationwide Analysis was documented in a summary report and 14 supporting appendices. The Specific Problem Analysis was documented by three published reports prepared by the 21 regional study groups; the State/Regional Future Report, Effect of Not Resolving Problems, and Summary Report.

The Nation's Water Resources includes the following parts and appendices:

Summary Report

Part I	Introduction
Part II	Water Management Problem Profiles
Part III	Functional Water Uses
Part IV	Water Supply and Water Quality Considerations
Part V	Regional Assessment Summaries and Regional Reports

Appendix A-1	Economic, Social, and Environmental Data
Appendix A-2	Water Supply and Use Data
Appendix A-3	Water Supply and Use Analyses
Appendix A-4	Streamflow Conditions

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PART III

CHAPTER 1

FUNCTIONAL WATER REQUIREMENTS AND MANAGEMENT CONSIDERATIONS

Historically, the location and rate of the United States' economic growth have been related to an inexpensive and relatively abundant supply of good quality water. Today, and in the future, water for both instream and offstream uses to meet economic and environmental needs can be provided only through reasonable and effective resource management in most regions of the Nation. Although the United States as a whole still has abundant supplies of water the continued expansion of growth centers will generate water needs which are projected to outstrip the available water in those areas. These pressures on water supplies will affect water uses directly as well as the related land resources.

Water resource problems are both geographic and temporal. For example, some regions with low rainfall have chronic surface water deficiencies, ground water overdraft problems, and occasional flooding. Other regions have abundant rainfall with frequent severe flooding problems and infrequent droughts. In many regions of the United States declining streamflows plus ground and surface water pollution are of major concern. In brief, almost every region has water resources management problems of one sort or other.

Interrelated water and land resource problems stem largely from a collection of socioeconomic changes resulting from the choices and decisions of individuals, firms, and governments. Urbanization and related pollution problems are of serious concern. Conversion of agricultural lands to urban-related uses and wetlands to urban and agricultural uses are other major concerns. In brief, competition for use of the Nation's water related land resources is continuing to increase, especially in and adjacent to urban growth centers.

The primary purpose of this Part of the Second National Water Assessment report is to focus on the National perspectives regarding existing (1975) and future (1985 and 2000) requirements for water to meet offstream, instream, and flow management needs for eleven major functional categories. State/Regional viewpoints are considered separately within this Part and in other Parts of this Assessment as an alternative for those situations in which there are major viewpoint differences or projections.

Functional Use and Management Areas

Projected economic conditions which provide the basis for the water use requirements are summarized in Chapter 2. The eleven functional use and related management categories, that are listed below are considered in terms of offstream, instream, and flow management parameters in Chapters 3-13:

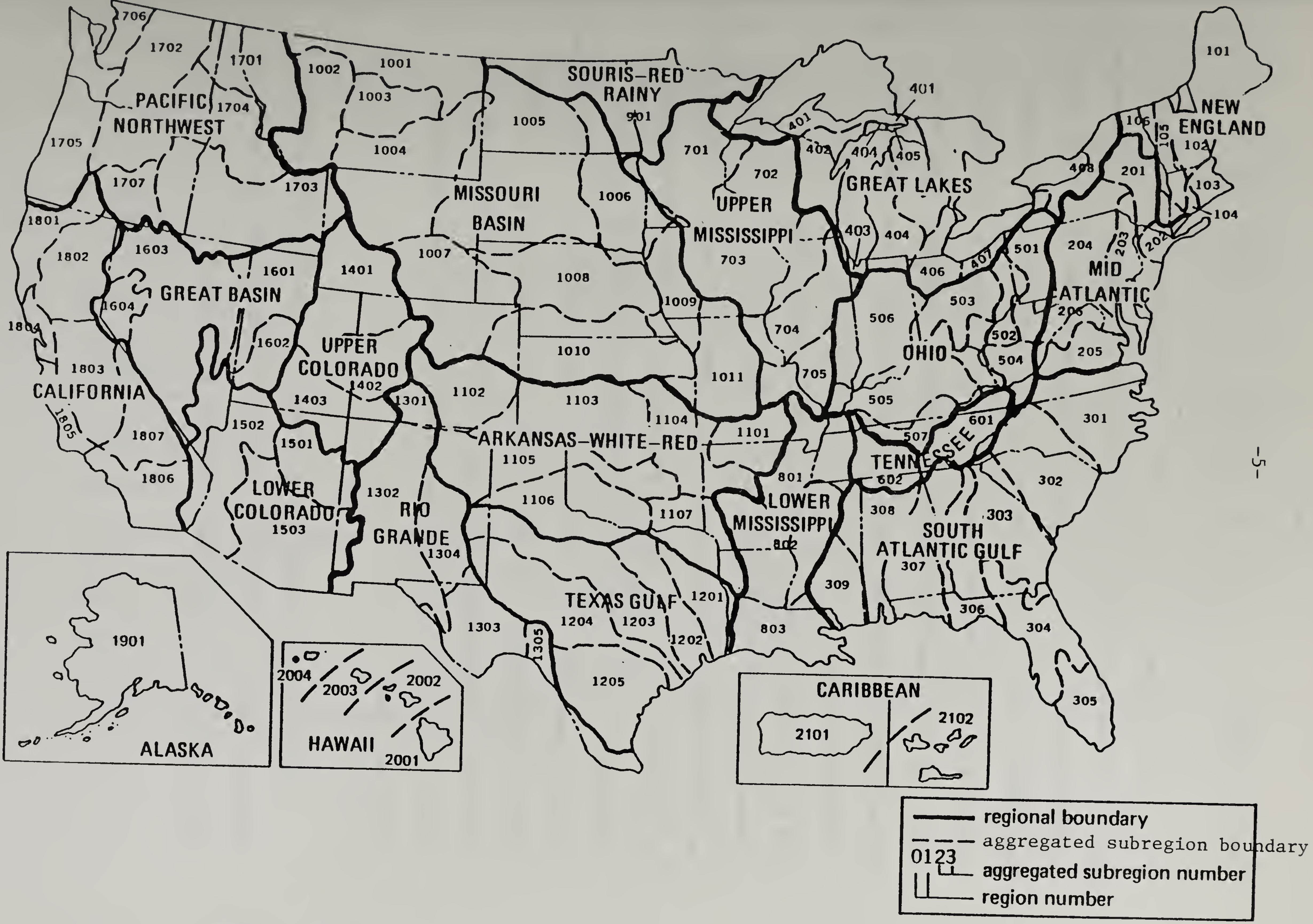
- Offstream Uses
  - Domestic and commercial needs,
  - Manufacturing and related needs,
  - Food and fiber production,
  - Energy production,
  - Mineral production,
- Instream Uses
  - Recreation activities,
  - Navigation requirements,
  - Fish and wildlife habitats,
  - Natural areas maintenance,
- Flow Management
  - Flood damage management, and
  - Erosion and sedimentation management.

The analyses of functional requirements were based on a future scenario for the economic and social needs of the Nation for basic products, services, and environmental conditions. Once these needs were determined the estimates for water withdrawals, consumptive use, reservations, and management needs for each category were projected in terms related to changing but readily identified components of the Nation's economic system and resource management specialities. This approach is important for identifying changing technologies, policies, and perceptions which influence water use and management requirements geographically and/or temporally.

Water uses and requirements for each of the offstream functions were determined for each of the 21 regions and 106 subregions into which the Nation was divided for this study (Figure III-1).

Summary of Offstream Functional Uses

Water use involves two variable components: withdrawal from a watercourse or aquifer and consumption of all or part of the amount withdrawn. Withdrawals may include saline waters, but the major concern of the Second Assessment is with freshwater withdrawals and consumption. Projections of uses and available water supplies (streamflow, ground water, imports, and exports) are analyzed in Part IV to identify the locations of critical water balances where they exist. The water use and supply comparisons are discussed in Part IV also.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SOURIS-RED RAINY
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MISSOURI BASIN
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ALASKA
1901
HAWAII
2001
2002
2003
2004
CARIBBEAN
2101
2102
regional boundary
aggregated subregion boundary
0123
aggregated subregion number
region number

Figure III-1: **WATER RESOURCES REGIONS AND AGGREGATED SUBREGIONS OF THE UNITED STATES**

Functional Uses

Total freshwater withdrawals for all offstream uses for an average year condition were 338.5 billion gallons per day (bgd) in 1975. Freshwater withdrawals are projected to decrease by 10 percent by 2000 or to 306.9 bgd (Table III-1). This projection reflects certain assumptions about water use efficiencies and recycling expected to develop from available technology and conservation efforts. The most significant contributor to reductions in offstream withdrawals will be made in the manufacturing sector where freshwater withdrawals are projected to decline from 51.2 bgd to 19.7 bgd or from 15 percent of the offstream total to only 6 percent between 1975 and 2000. Smaller reductions in withdrawals will be made in other sectors, however, the proportion of withdrawals represented by irrigation and steam electric generation will remain essentially unchanged at about one-half for irrigation and one-fourth for steam electric generation (Table III-1). All other offstream uses will increase both their withdrawals and their share of total withdrawals. In summary, the largest withdrawals of freshwater are made by agriculture and steam electric generation -- more than three-fourths of the total for all offstream uses.

The Nation's consumptive use of water is generally more critical than withdrawals. The Nation's offstream consumptive use averaged 106.6 bgd in 1975 and is projected to increase by 26 percent to 134.4 bgd by

ANNUAL WATER REQUIREMENTS FOR OFFSTREAM USES; AVERAGE YEAR

(Million Gallons Per Day)

Type of Use	Total Withdrawals 1975	1985	2000	Total Withdrawals 1975	1985	2000
Domestic and Commercial						
Central (Municipal)	21,164	23,983	27,918	4,976	5,665	6,638
Non-Central (Rural)	2,092	2,321	2,401	1,294	1,409	1,439
Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Manufacturing	51,210	23,664	19,661	6,049	8,893	14,686
Agriculture						
Irrigation	158,743	166,252	153,846	86,391	92,820	92,506
Livestock	1,912	2,233	2,551	1,912	2,233	2,551
Steam Electric	88,904	94,855	80,052	1,418	4,062	10,544
Minerals	7,055	8,832	11,328	2,196	2,777	3,609
Public Lands and Other*	1,845	2,125	2,425	1,216	1,449	1,712
Total, Freshwater	338,455	330,313	306,914	106,561	120,524	135,054
Total, Saline	59,747	91,239	118,815			
TOTAL	398,202	421,552	425,729			

* Fish hatcheries and miscellaneous uses.

2000 (Table III-1). Consumptive use is not equally proportionate to withdrawals among the functional use categories. For example, agriculture (irrigation and livestock watering) is the most highly consumptive user of water relative to all other consumptive uses. Agriculture accounted for 83 percent of the total water consumed in 1975, but this will decline to about 70 percent in 2000 because of higher consumption to withdrawal ratios developing in steam electric generation and manufacturing (Table III-2).

The Nation's overall consumption to withdrawal ratio is projected to increase from 32 percent in 1975 to 44 percent in 2000 due to substantial increases in recycling rates and use efficiencies which reduce withdrawals and return flows. The consumption to withdrawal ratio for irrigation will increase from 55 percent to 61 percent by 2000. In steam-electric generation the ratio will increase from 2 percent to 13 percent as plants change from oncethrough cooling to recycling and/or other methods of cooling. The largest increase in the consumption to withdrawal ratio will occur in manufacturing -- from 12 to 75 percent.

Regional Uses

Withdrawal and consumption of water varies greatly among the 21 regions -- depending partly on variations in population, income, and dominant type of employment. In 1975 the largest withdrawals were made

TABLE III-2
SUMMARY OF FRESHWATER WITHDRAWAL AND CONSUMPTIVE USE RELATIONSHIPS BY INDUSTRY SECTOR; AVERAGE YEAR

(BILLION GALLONS PER DAY)

Type of Use	Withdrawals		Consumption		Consumption as a percent of withdrawals
	(bgd)	(percent)	(bgd)	(percent)	(percent)
			1975		
Agriculture (Irrigation, Livestock)	160.7	47	88.3	83	55
Steam Electric Generation	88.9	26	1.4	1	2
Manufacturing	51.2	15	6.0	6	12
Domestic	23.3	7	6.3	6	27
Commercial	5.5	2	1.1	1	20
Minerals	7.1	2	2.2	2	31
Other	1.8	1	1.3	1	72
Total, Regions 1-21	338.5	100	106.6	100	32
			2000		
Agriculture (Irrigation, Livestock)	156.4	51	95.1	70	61
Steam Electric Generation	80.1	26	10.5	8	13
Manufacturing	19.7	6	14.7	11	75
Domestic	30.3	10	8.1	6	27
Commercial	6.7	2	1.4	1	21
Minerals	11.3	4	3.6	3	32
Other	2.4	1	1.7	1	71
Total, Regions 1-21	306.9	100	135.1	100	44

in the Great Lakes, Ohio, Missouri, Pacific Northwest, and California Regions with substantial amounts in the South Atlantic-Gulf, Texas-Gulf, and Lower Mississippi (Table III-3).

In 1975 the largest consumptive use occurred in the Missouri, Texas-Gulf, Pacific Northwest, and California Regions -- due largely to agriculture. In 2000 these four regions will remain the largest consumptive users, but the South Atlantic-Gulf will more than double its consumptive use to become the fifth major consumptive user.

For convenience one may look at the relative per capita withdrawals and consumption in each of the 21 regions. This reflects the population density as well as the relative mix of water intensive industries in each region (Table III-4). In 1975 the Nation had a per capita withdrawal rate of 1554 gpd and a consumption rate of 492 gallons per day (gpd). By 2000 the per capita withdrawal rate is projected to decline by 27 percent to 1140 gpd, but the per capita consumption rate will be almost unchanged at 506 gpd. The highest per capita withdrawals are made in the Upper Colorado Region at a rate of about 20,000 gpd -- a rate nearly 50 times greater than in the New England and Mid-Atlantic Regions. It is significant that the rate in the Upper Colorado and other Western regions is not projected to decline by 2000, but rates in some regions

Table III-3
SUMMARY OF WATER WITHDRAWALS AND CONSUMPTION FOR ALL FUNCTIONAL USES BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR

(Million Gallons Per Day)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	5,094	3,935	3,231	80	644	1,059
Mid-Atlantic	18,297	15,854	13,869	1,839	2,471	3,542
South Atlantic-Gulf	24,512	25,453	28,338	4,867	6,777	10,054
Great Lakes	42,809	32,330	25,621	2,593	3,298	4,692
Ohio	34,927	27,835	16,923	1,798	2,525	4,331
Tennessee	7,412	7,129	6,012	314	644	1,103
Upper Mississippi	12,397	10,377	7,908	1,144	1,000	2,687
Lower Mississippi	14,562	17,453	24,839	4,025	4,553	5,510
Souris-Red-Rainy	337	327	587	112	202	446
Missouri	38,016	48,030	44,354	15,463	19,203	19,910
Arkansas-White-Red	12,867	13,797	13,333	8,062	8,766	8,886
Texas-Gulf	16,925	15,930	15,538	11,262	10,225	10,530
Rio Grande	6,318	6,199	5,630	4,240	4,320	4,017
Upper Colorado	6,868	7,841	7,519	2,441	3,017	3,232
Lower Colorado	8,915	8,527	7,858	4,597	4,755	4,708
Great Basin	7,989	7,312	7,258	3,778	3,763	4,034
Pacific Northwest	37,493	38,100	33,843	11,905	14,615	15,193
California	39,635	40,542	41,259	26,637	27,929	29,699
Alaska	295	430	756	58	206	457
Hawaii	1,879	1,619	1,350	603	637	665
Caribbean	908	963	888	343	374	299
Total, Regions 1-18	335,373	327,301	303,920	105,557	119,307	133,633
Total, Regions 1-21	338,455	330,313	306,914	106,561	120,524	135,054

TABLE III-4
SUMMARY OF PER CAPITA TOTAL WATER WITHDRAWALS AND CONSUMPTION AND DOMESTIC WITHDRAWALS BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR

MILLION GALLONS PER DAY

Region	Per Capita Withdrawals For All Offstream Uses			Per Capita Consumption For All Offstream Uses			Per Capita Withdrawals All Domestic Uses		
	1975	1985	2000	1975	1985	2000	1975	1985	2000
New England	408	289	211	38	47	69	90	90	89
Mid-Atlantic	462	361	278	46	56	71	100	102	103
South Atlantic-Gulf	882	867	816	191	230	289	90	95	101
Great Lakes	1408	994	705	85	101	129	107	110	112
Ohio	1650	1224	682	84	111	174	87	91	95
Tennessee	2078	1766	1302	87	159	238	74	79	83
Upper Mississippi	924	718	498	84	109	168	108	112	114
Lower Mississippi	2269	2578	3477	626	672	771	102	107	111
Souris-Red-Rainy	515	518	980	168	318	743	82	90	94
Missouri	4304	5162	4700	1746	2060	2189	109	112	116
Arkansas-White-Red	1876	1895	1258	1174	1203	841	107	111	114
Texas-Gulf	1707	1426	1203	1135	915	815	122	124	126
Rio Grande	3725	3480	2710	2498	2424	1941	156	161	166
Upper Colorado	19980	22003	20429	7108	8490	8785	203	213	226
Lower Colorado	3694	2923	2163	1903	1629	1295	175	178	181
Great Basin	6338	4997	4174	2998	2572	2320	269	273	273
Pacific Northwest	5612	5457	4468	1775	2093	2007	120	123	126
California	1873	1710	1522	1259	1178	1096	142	143	144
Alaska	961	1191	1726	189	571	1043	273	291	313
Hawaii	2388	1777	1244	766	699	613	189	190	194
Caribbean	292	260	202	109	208	66	97	97	99
Regions 1-18	1570	1403	1154	497	511	506	107	110	113
Regions 1-21	1554	1387	1140	492	506	501	107	110	113

will be reduced substantially. By 2000 the Upper Colorado per capita daily withdrawal rate will be nearly 100 times greater than the rates in the Northeast.

Similar comparisons exist for consumptive uses in the Upper Colorado Region. Per capita consumption rates are projected to be 125 to 140 times those in the Northeast. Most western regions will consumptively use water at per capita rates of around 1000 gpd. This is more than 20 times the national average. These rates are largely due to the relative concentration of irrigated agriculture, mining, and steam electric generation in the West.

Total water withdrawals are about fifteen times the domestic withdrawals for 1975 and about ten times the domestic withdrawals for 2000. All domestic uses now average about 110 gallons per capita per day with little change estimated by 2000. In summary, most of the Nation's withdrawal and consumption of water are in support of producing food and fiber, energy, and manufactured goods and services. The greatest opportunities for effecting more efficient allocations and uses are in these offstream functional areas.

PART III

CHAPTER 2

ECONOMIC CHARACTERISTICS AND PROJECTIONS

A nation's economy -- the population; its productivity, income, geographic distribution, trade and travel activities, lifestyles, and even its sense of values -- affect the requirements for water and determine the necessary management considerations.

Additional knowledge of existing requirements for water is needed for fully assessing the adequacy of supplies and limitations on needs for future conditions. However, significant advances in data resources and methods of evaluation are being introduced in parts of this Assessment to improve water planning and management functions. The physical characteristics of the water resource (flows, volumes, and qualities) sometimes limit its availability or require substantial investment of capital resources and time to alter these characteristics. A major change in population growth, a shift in its geographical location or a change in the composition (age, family size, occupation, etc.) will affect the level, distribution, and mix of water requirements for the Nation and each region. The earnings, incomes, and lifestyles of the population affect the priorities for using the Nation's waters.

Increasing real incomes and leisure time tend to place higher priorities on instream water uses for recreation, fish and wildlife, natural areas, and related resources vis-a-vis the traditional offstream uses. A general concern for maintaining and improving the quality of the environment for its inherent, as well as functional, value is a significant factor in managing water resources to meet the Nation's needs. All indications are that these preferences for cleaner waters, as well as responsible use and management for meeting a full range of economic and environmental objectives, will continue to influence decisions in the United States during the period 1975-2000. In fact, many traditional economic and water use relationships may change substantially as relative prices, incomes, asset values, and productivities adjust in response to changing energy and trade relationships. The Second Assessment provides scenarios and opportunities for analysis of two or more futures projected for the Nation's economy and its environment.

Population

The future size and geographic distribution of population and the level of economic activity are major considerations in water and related land resources management. The Second Assessment is based on two somewhat different sets of projections of economic activity and population growth; one for the National Future (NF) and one for the State/Regional Future

(SRF).* These projections of population growth indicate that greater attention to planning and management to serve water resources needs will be required.

In the 25 years from 1950 to 1975 the population of the United States increased by 62 million, from about 154 million to 216 million. This is an increase of 40 percent, or an annual growth rate of 1.36 percent. However, during the 25-year period from 1975 to 2000, the national population is expected to increase to about 268 million. This expected increase of 52 million, or 24 percent, is an average annual growth rate of only 0.86 percent (Table III-5 and Figure III-2).

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*The economic and demographic projections for the National Future are based primarily on the 1972 OBERS Projections Series E Population published by the Water Resources Council. The OBERS projections are a nationally consistent set of data on population and economic growth for the Nation and its geographic regions. The projections are prepared by the Bureau of Economic Analysis (BEA) U.S. Department of Commerce, and the Economic Research Service (ERS), U.S. Department of Agriculture. The National population projection used as a starting point is the Census Bureau's "Series E" projection based on a birth rate assumption which would in time yield a zero population growth, exclusive of immigration. This has been the approximate birth rate of the period from 1970 to 1975. For the 21 Water Resources Regions, the State/Regional Futures are projections prepared either by the Assessment team in each region, or selected from available projections prepared by or for State agencies. The regions include 18 water resource regions for the conterminous states, one each for Hawaii and Alaska (20 for the 50 States) and 1 region for the Caribbean territories. These regions are aggregated from 106 subareas on the basis of hydrologic parameters.

TABLE III-5
SUMMARY OF SELECTED ECONOMIC PROJECTIONS FOR THE SECOND NATIONAL WATER ASSESSMENT REGIONAL AGGREGATES - 1975, 1985, 2000

Economic Indicator	Regional Aggregate	Units	Actual		Projections		
			1950	1975	1975	1985	2000
Population	1-18	Million persons	151.7	213.0	212.3	233.2	262.3
	1-20	" "	152.3		213.5	234.4	263.8
	1-21	" "	154.5		216.4	238.1	268.1
Employment	1-18	" "	58.9	84.8	87.6	100.5	117.2
	1-20	" "			88.1	101.1	117.9
	1-21	" "			88.9	102.1	119.1
Gross National Product	1-18	Billion 1972$	533.5		1223.5*	1940.4	3134.1
	1-20	" "	- -	1191.7	1516.3		
Total Personal Income	1-20	1972$	377.1		1048.8	1538.1	2602.4
	1-18	1975$	226.1 **		1323.0	1939.5	3281.7
	1-20	1975$		1249.7	1330.9	1951.3	3302.3
	1-21	" "			1340.6	1974.3	3345.1
Per Capita Income	1-18	1975$/person	149.1 **		6233	8318	12511
	1-20	" "	--	5832			
	1-21	" "	--		6195	8197	12319
Total Earnings	1-20	Billion 1972$	311.1		827.6	1199.2	2002.1
	1-18	" 1975$			1043.4	1511.4	2523.5
	1-20	" 1975$			1050.3	1521.5	2540.7
	1-21	" 1975$			1057.9	NC	NC

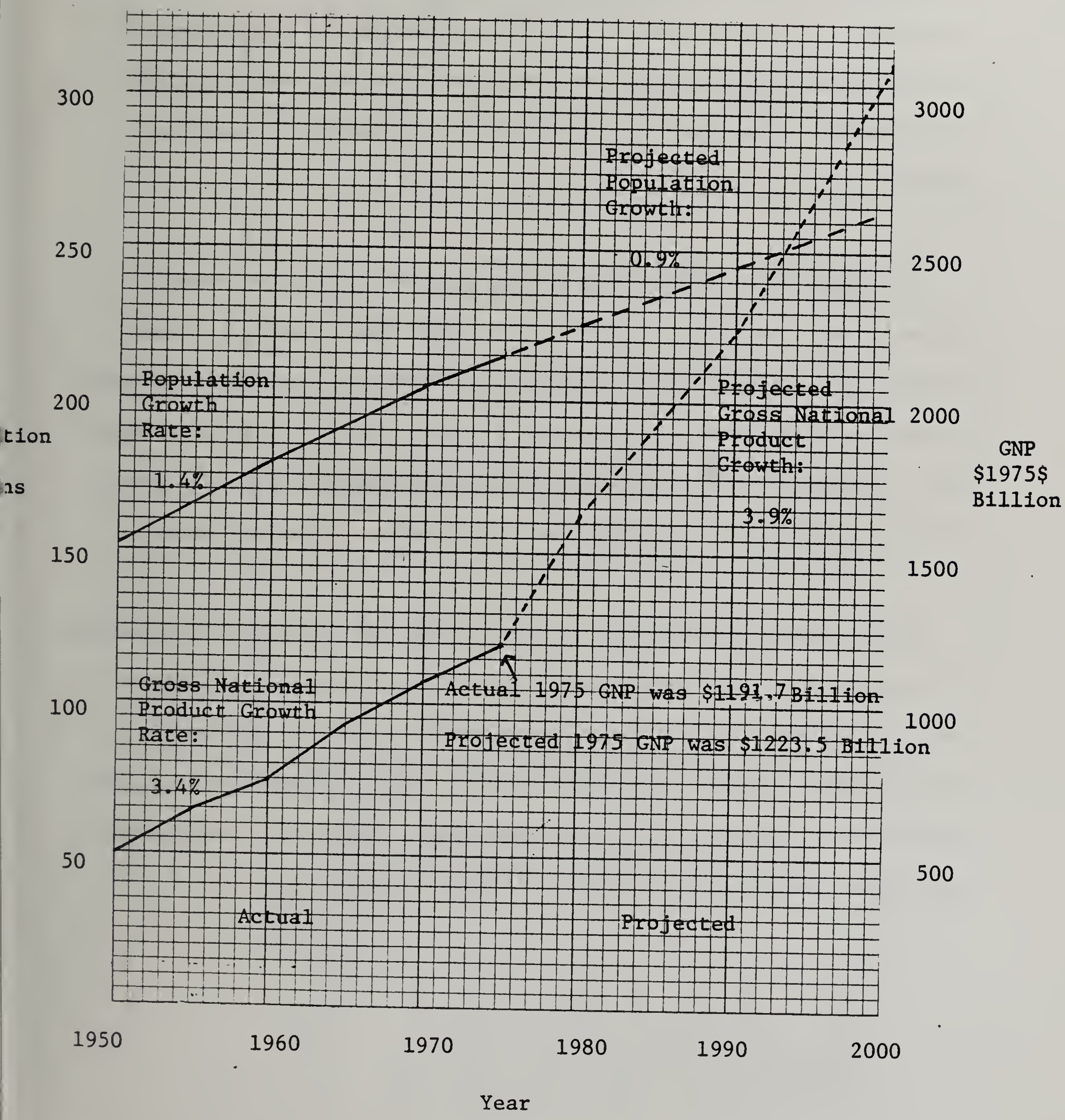
* The 1975 projected gross national product. The actual 1975 gross national product was $1191.7 billion.

**In 1950$.

(NC) Not Computed.

Figure III-2

POPULATION AND GROSS NATIONAL PRODUCT
GROWTH FOR THE NATION, 1950-2000



Historically (1950-1975) the largest increases in population occurred in the California Region, with an increase of 10 million (98 percent). This was closely followed by the Mid-Atlantic and South Atlantic-Gulf Regions, with increases of over 9 million each, 31 and 60 percent respectively. The smaller regions of the West had large percentage increases. The Upper Colorado led with an increase of 203 percent or 1.8 million while the Great Basin increased by 84 percent or 630,000. The Texas-Gulf's population increased by 65 percent or 4.1 million persons.

In recent years (1970-1975) the largest percentage increases in population have occurred in the South Atlantic-Gulf Region, with an increase of 2.5 million (11.2 percent), and the Lower and Upper Colorado Regions, with increases of 500 and 82 thousand respectively (24 percent each). The Mid-Atlantic and Great Lakes Regions experienced the lowest relative increases of about 300 thousand or only a 1 percent change.

The geographic distribution of population has important implications for the Nation's water resources (Table III-6). Projections indicate that the southern and outlying (Alaska, Hawaii, and the Caribbean) regions large increases in population will occur. Moderate population growth is also projected for the Tennessee, Mid-Atlantic, New England, Great Lakes, and California Regions (Figure III-3).

TABLE III-6
SUMMARY OF REGIONAL ECONOMIC PROJECTIONS FOR THE SECOND NATIONAL WATER ASSESSMENT
1975 - 2000

Region	Proportion of Total Population in SMSA's	Population Projections		Growth Rate	Personal Income		Growth Rate	Total Earnings		Growth Rate
	1975	1975	2000	1975-2000	1975	2000	1975-2000	1975	2000	1975-2000
	(percent)	(million persons)		(percent)	(billion 1975$)		(percent)	(billion 1975 $)		(percent)
New England	84.3	12.5	15.3	0.81	83.3	204.3	3.70	63.6	153.4	3.58
Mid-Atlantic	87.6	39.6	49.9	0.93	282.6	692.4	3.65	222.6	540.1	3.61
South Atlantic-Gulf	61.3	25.4	34.7	1.26	134.0	380.2	4.26	104.9	281.5	4.03
Great Lakes	85.6	30.4	36.4	0.72	205.8	490.6	3.53	167.8	387.0	3.40
Ohio	62.4	21.2	24.8	0.63	119.4	290.4	3.62	95.0	225.2	3.51
Tennessee	52.0	3.6	4.6	0.99	16.2	45.7	4.24	12.9	35.4	4.12
Upper Mississippi	56.4	13.4	15.8	0.66	83.2	198.2	3.53	65.3	152.0	3.44
Lower Mississippi	45.9	6.4	7.1	0.42	30.7	72.8	3.51	23.9	55.4	3.42
Souris-Red-Rainy	18.4	0.6	0.6	0.29	3.2	6.2	2.68	2.4	4.6	2.64
Missouri	52.6	8.8	10.0	0.51	52.6	121.0	3.39	41.0	92.4	3.30
Arkansas-White-Red	53.6	6.8	7.8	0.55	35.9	85.2	3.52	27.0	63.2	3.46
Texas-Gulf	79.2	9.9	12.9	1.06	57.5	152.2	3.97	45.8	118.2	3.87
Rio Grande	64.8	1.7	1.9	0.45	8.1	18.6	3.38	6.3	14.3	3.33
Upper Colorado	-0-	0.3	0.4	0.27	1.7	3.8	3.27	1.3	2.9	3.26
Lower Colorado	74.8	2.4	3.6	1.64	14.0	40.5	4.34	11.3	31.6	4.20
Great Basin	79.6	1.3	1.7	1.28	7.1	19.9	4.21	6.0	16.1	4.03
Pacific Northwest	59.3	6.7	7.6	0.51	39.6	93.1	3.46	30.9	70.8	3.37
California	92.6	21.2	27.1	0.99	147.8	366.4	3.70	115.4	279.4	3.60
Alaska	44.0	0.3	0.4	1.45	2.3	6.3	4.11	2.2	5.5	3.73
Hawaii	81.2	0.8	1.1	1.28	5.7	14.7	3.86	4.7	11.7	3.72
Caribbean		3.1	4.2	1.29	9.8	42.8	6.07	7.7	-	-
Total, Regions 1-18		212.3	262.3	0.85	1323.0	3281.7	3.66	1043.4	2523.5	3.60
Total, Regions 1-21		216.4	268.1	0.86	1340.6	3302.3	3.67	1057.9	2540.7	3.60

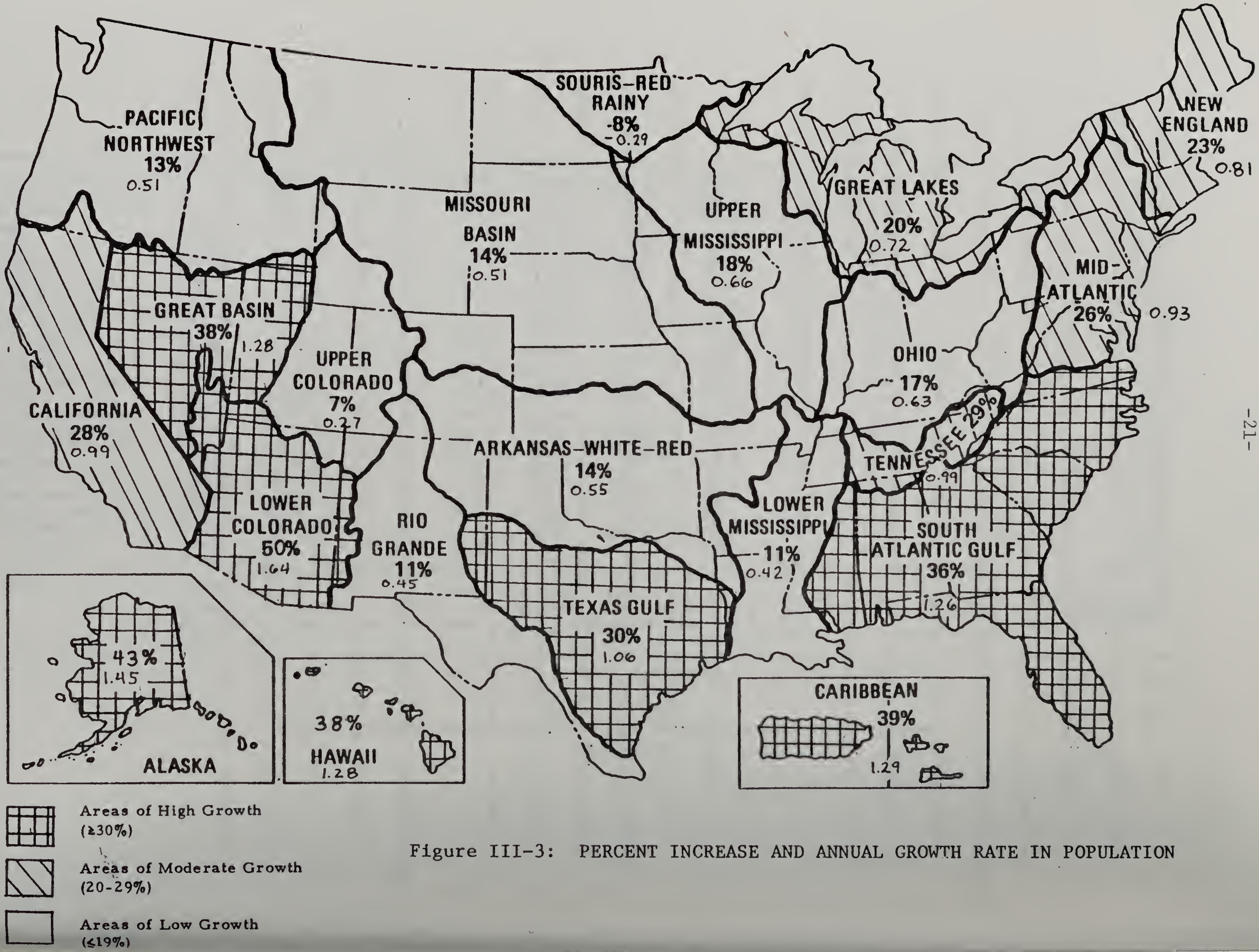

PACIFIC NORTHWEST
13%
0.51
CALIFORNIA
28%
0.99
GREAT BASIN
38%
1.28
UPPER COLORADO
7%
0.27
LOWER COLORADO
50%
1.64
MISSOURI BASIN
14%
0.51
SOURIS-RED RAINY
-8%
-0.29
RIO GRANDE
11%
0.45
ARKANSAS-WHITE-RED
14%
0.55
TEXAS GULF
30%
1.06
UPPER MISSISSIPPI
18%
0.66
LOWER MISSISSIPPI
11%
0.42
GREAT LAKES
20%
0.72
OHIO
17%
0.63
TENNESSEE 29%
0.99
SOUTH ATLANTIC GULF
36%
1.26
MID-ATLANTIC
26%
0.93
NEW ENGLAND
23%
0.81
ALASKA
43%
1.45
HAWAII
38%
1.28
CARIBBEAN
39%
1.29
▦ Areas of High Growth (≥30%)
▧ Areas of Moderate Growth (20-29%)
☐ Areas of Low Growth (≤19%)

Figure III-3: PERCENT INCREASE AND ANNUAL GROWTH RATE IN POPULATION

The density of population is a general index that reflects pressures on the Nation's water resources for many uses. Between 1950 and 1975 the average population density increased from 43 to 61 persons per square mile. Given the projected increases in population to 268 million in 2000 the density will increase to about 76 persons per square mile. However, population densities among regions vary from a high of 859 per square mile in the Caribbean to 3 and 1 per square mile in the Upper Colorado and Alaska Regions, respectively (Figure III-4).

Generally, regions with large metropolitian areas have population densities in excess of 100 persons per square mile (New England, Mid-Atlantic, Caribbean, Great Lakes, Ohio, California, and Hawaii). The agricultural areas have low population densities of less than 75 persons per square mile (Lower Mississippi and all regions west of the Mississippi Valley except California). The urban nature of the population of all regions is evident when one considers that more than one-half of the population of all but 4 regions (Lower Mississippi, Souris-Red-Rainy, Upper Colorado, and Alaska) are included within designated Standard Metropolitian Statistical Areas (Table III-6).

These differences in population densities and in types of land use affect the nature of the water use problems and the needs for water resources development and management. In the humid, more densely populated

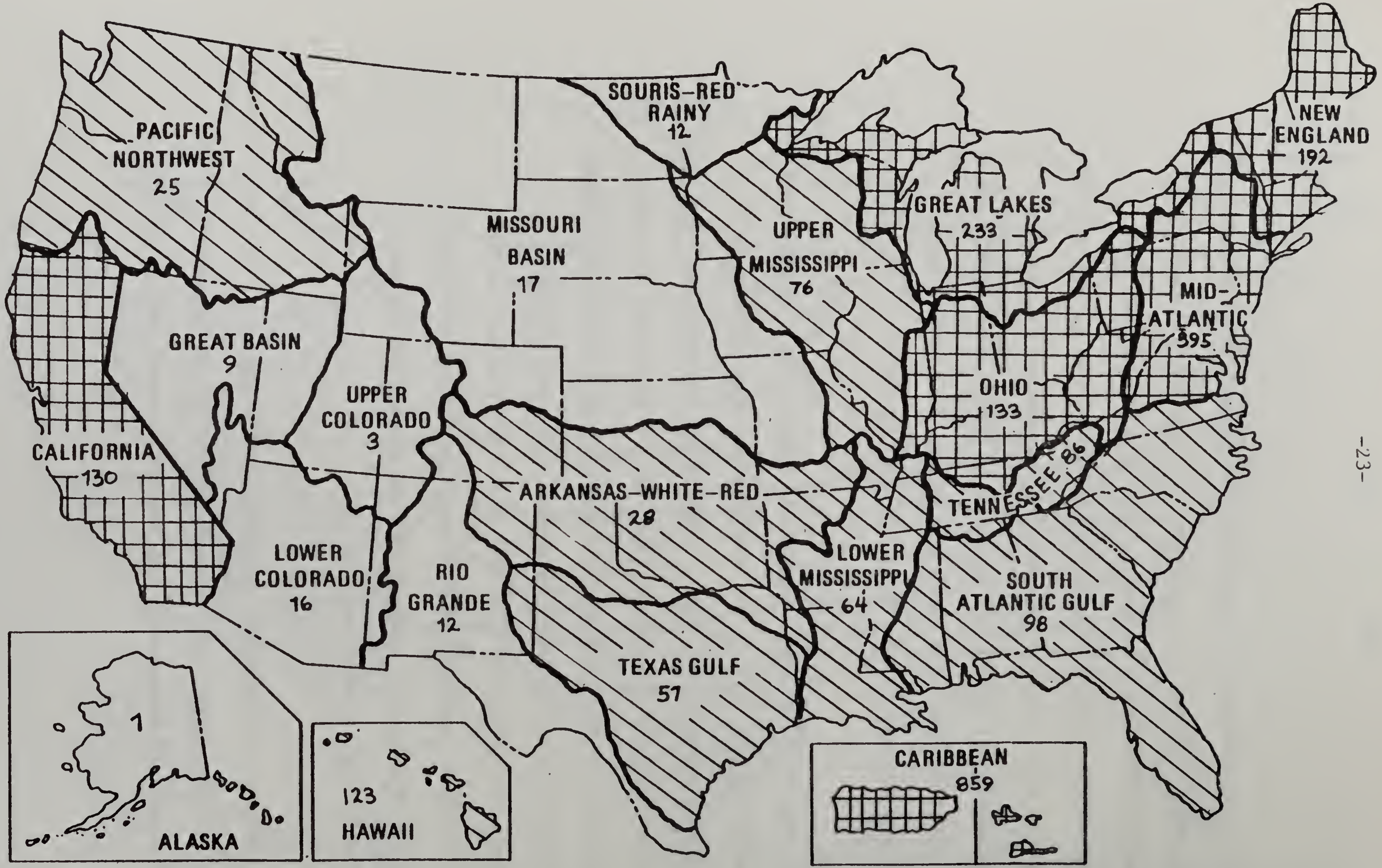

PACIFIC NORTHWEST
25
CALIFORNIA
130
GREAT BASIN
9
UPPER COLORADO
3
LOWER COLORADO
16
MISSOURI BASIN
17
SOURIS-RED RAINY
12
RIO GRANDE
12
ARKANSAS-WHITE-RED
28
TEXAS GULF
57
UPPER MISSISSIPPI
76
LOWER MISSISSIPPI
64
GREAT LAKES
233
OHIO
133
TENNESSEE
86
SOUTH ATLANTIC GULF
98
MID-ATLANTIC
395
NEW ENGLAND
192
1
ALASKA
123
HAWAII
CARIBBEAN
859
▦ ≥130 PER SQ MI OF LAND AREA
▨ 25-129 PER SQ MI OF LAND AREA
☐ < 25 PER SQ MI OF LAND AREA

FIGURE III-4: 1975 POPULATION DENSITY BY WATER RESOURCE REGIONS

regions of the country water-related problems stem from the pressures of flooding and domestic, commercial, and manufacturing uses related to both quantity and quality. In the more arid, sparsely populated parts of the country the more pervasive water resource problems are related to the uses of water in utilizing the abundant lands and mineral resources. i.e. in irrigated agriculture and mining.

Employment

Employment is expected to grow from 89 million (41 percent of the population) in 1975 to about 119 million (44 percent of the population) by 2000. This is a growth of about 1.15 percent annually which is somewhat higher than the projected population growth rate. This employment rate results from more women in the workforce, more liberal extension of retirement ages and post retirement employment, earlier entry of youth into the work force, and other factors which result concurrently in rising employment.

Employment is projected to increase most rapidly in the southern regions (South Atlantic-Gulf, Tennessee, Texas-Gulf, Lower Colorado, and Great Basin) and outlying regions (Alaska, Hawaii, and Caribbean) where employment increases of more than 40 percent are projected by 2000. The national average increase over this period will be only 34 percent.

Gross National Product

Gross national product, the measure of the Nation's production of goods and services, grows over the long-run more rapidly than population because of increases in productivity. GNP has fluctuated considerably in the past with a most recent decline in growth recorded in the mid-1970s (Figure III-2, Table III-5). Actual GNP was only $1,192 billion when the average or projected GNP was about $1,224 billion in 1972 dollars. Projected growth in production is based on the assumption that an economy with essentially full employment and continued increases in productivity will be maintained over the long-run despite intermittent international and domestic problems.

The long-run growth in GNP was at a 3.4 percent annual rate from 1970 to 1975. Growth in GNP is projected to increase to about a 3.9 percent annual rate over the period, 1975-2000 (Table III-7). This indicator of national economic output is not available on a consistent basis for regional and sector comparisons of economic activity, but surrogate values, such as personal income and earnings, are useful in relating economic activity to emerging water resource supply, demand, and management conditions.

Personal Income And Earnings

Total personal income is the most reliable indicator of regional economic activity available. Earnings of persons, referred to in the

Table III-7
SELECTED GROWTH INDICATORS -- 1950 -1975, 1975-2000

Indicator	Annual Rate 1950-1975	Annual Rate 1975-2000
Population	1.36	0.86
Employment	--	1.15
Gross National Product	3.38	3.86
Total Personal Income	4.20	3.69
Per Capita Income	5.60	2.79
Total Earnings	3.15	3.62
Manufacturing Earnings	3.06	3.07
Agricultural Earnings	0.11	3.07
Mining Earnings	2.18	1.22
All Other Earnings	--	3.87

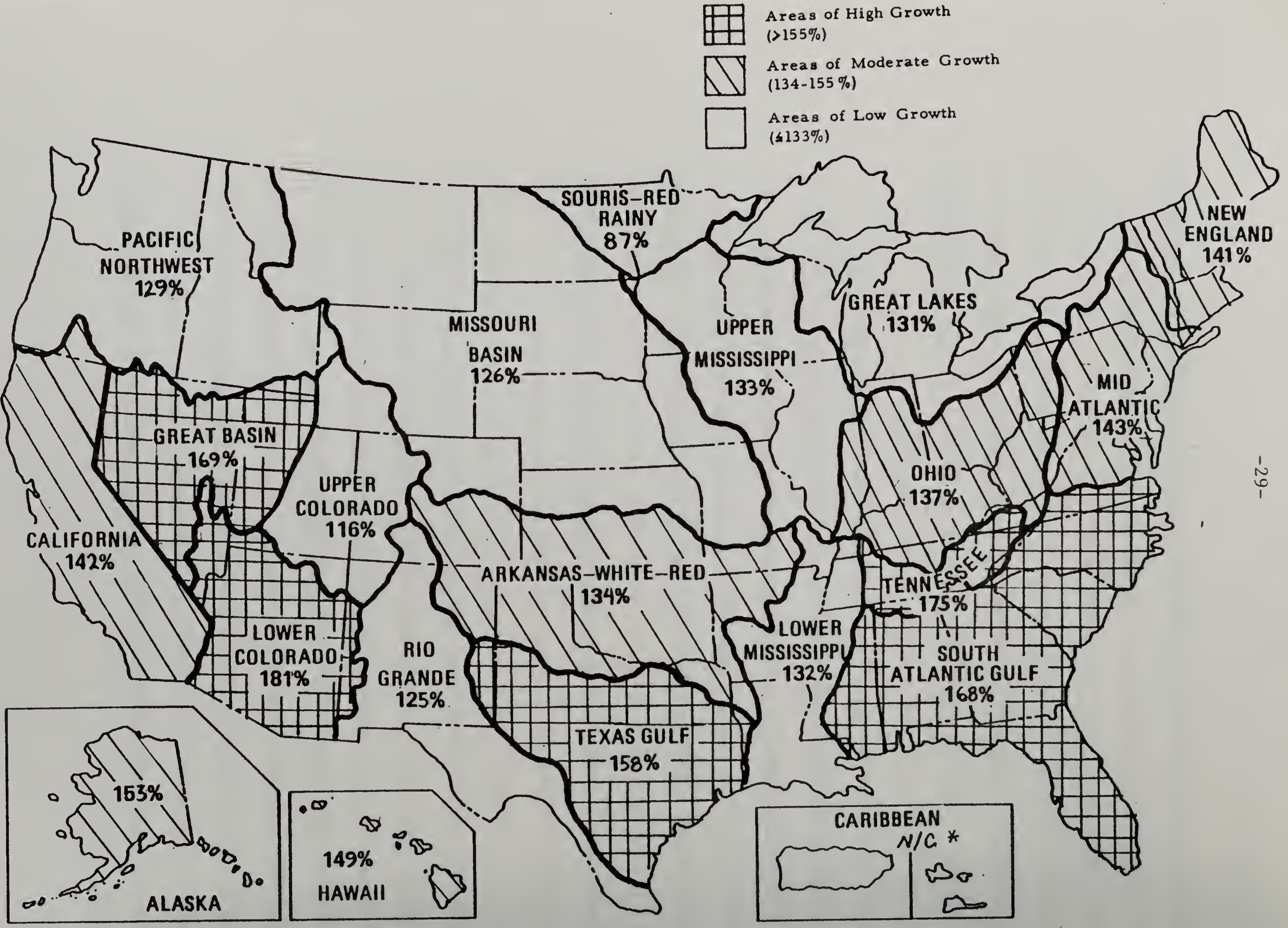
Assessment as "earnings", is that component of personal income which is derived from industrial services and agricultural activities. It represents about 75 percent of total personal income. The other components of personal income are transfer payments (social security and unemployment benefits) and property income (rents, interest, and dividends).

The personal income for all the 21 water resource regions was $1,341 billion (1975$) in 1975. Projections for the Assessment indicate that personal income grew much faster than population, employment, or GNP during the 1950-1975 period an annual rate of 4.2 percent. Growth in personal income for 1975-2000 is projected to decline to a rate of about 3.7 percent annually. This is near the 3.9 percent growth rate expected for GNP and about the same rate as total earnings (Table III-6).

The faster growth rates in personal incomes are likely to occur in the Southeast, East, and West (Table III-6). Growth rates in personal income are projected to exceed the national average (i.e. 4 percent or more annually) in the South Atlantic-Gulf, Tennessee, Texas-Gulf, Lower Colorado, Great Basin, Alaska, and Caribbean Regions. Relatively slower growth in personal incomes are expected in the Souris-Red-Rainy, Missouri, Rio Grande, and Upper Colorado Regions (less than 3.4 percent annually). Above average growth in personal incomes are not necessarily correlated with population growth. For example, New England is projected to experience slightly above average growth in personal income but lower than average growth in population.

Per capita incomes are generally lower in the southern and southwestern regions (Table III-8). Projections of per capita incomes indicate above average growth for the South Atlantic-Gulf, Ohio, Tennessee, Lower Mississippi, Souris-Red-Rainy, Arkansas-White-Red, Rio Grande, Upper Colorado, and Pacific Northwest Regions. The latter six regions will be slow growing in population as relative incomes increase, but absolute per capita incomes will remain below the national average. Water uses will be more difficult to evaluate in regions with mixed economic futures.

Perhaps the most useful and widely available economic indicator of water uses and emerging water resource management problems in this Assessment is earnings. Total earnings and earnings by major industry (i.e., manufacturing, agriculture, mining, and other) are available by regions as an indicator of levels and mixes of economic activities. Total earnings for the 50 states (Regions 1-20) were projected to be about $1,050 billion (1975$) with growth to $1,521 billion and $2,540 billion in 1985 and 2000 respectively (Table III-5). This 3.62 percent annual growth rate (1975-2000) is significantly greater than the 3.15 percent growth rate experienced during the previous quarter century (1950-1975) and generally consistent with growth rates in GNP and personal income (Table III-7).


Areas of High Growth (>155%)
Areas of Moderate Growth (134-155%)
Areas of Low Growth (≤133%)
PACIFIC NORTHWEST 129%
SOURIS-RED RAINY 87%
MISSOURI BASIN 126%
UPPER MISSISSIPPI 133%
GREAT LAKES 131%
NEW ENGLAND 141%
MID ATLANTIC 143%
OHIO 137%
GREAT BASIN 169%
UPPER COLORADO 116%
CALIFORNIA 142%
ARKANSAS-WHITE-RED 134%
TENNESSEE 175%
LOWER COLORADO 181%
RIO GRANDE 125%
LOWER MISSISSIPPI 132%
SOUTH ATLANTIC GULF 168%
TEXAS GULF 158%
153%
ALASKA
149%
HAWAII
CARIBBEAN
N/C *

*N/C = Not computable

Figure III-5: **PERCENT INCREASE IN EARNINGS BY WATER** RESOURCES REGIONS 1975 - 2000

Table III-8
SUMMARY OF PER CAPITA INCOME AND EARNINGS BY REGIONS, 1972-2000
(1975 DOLLARS)

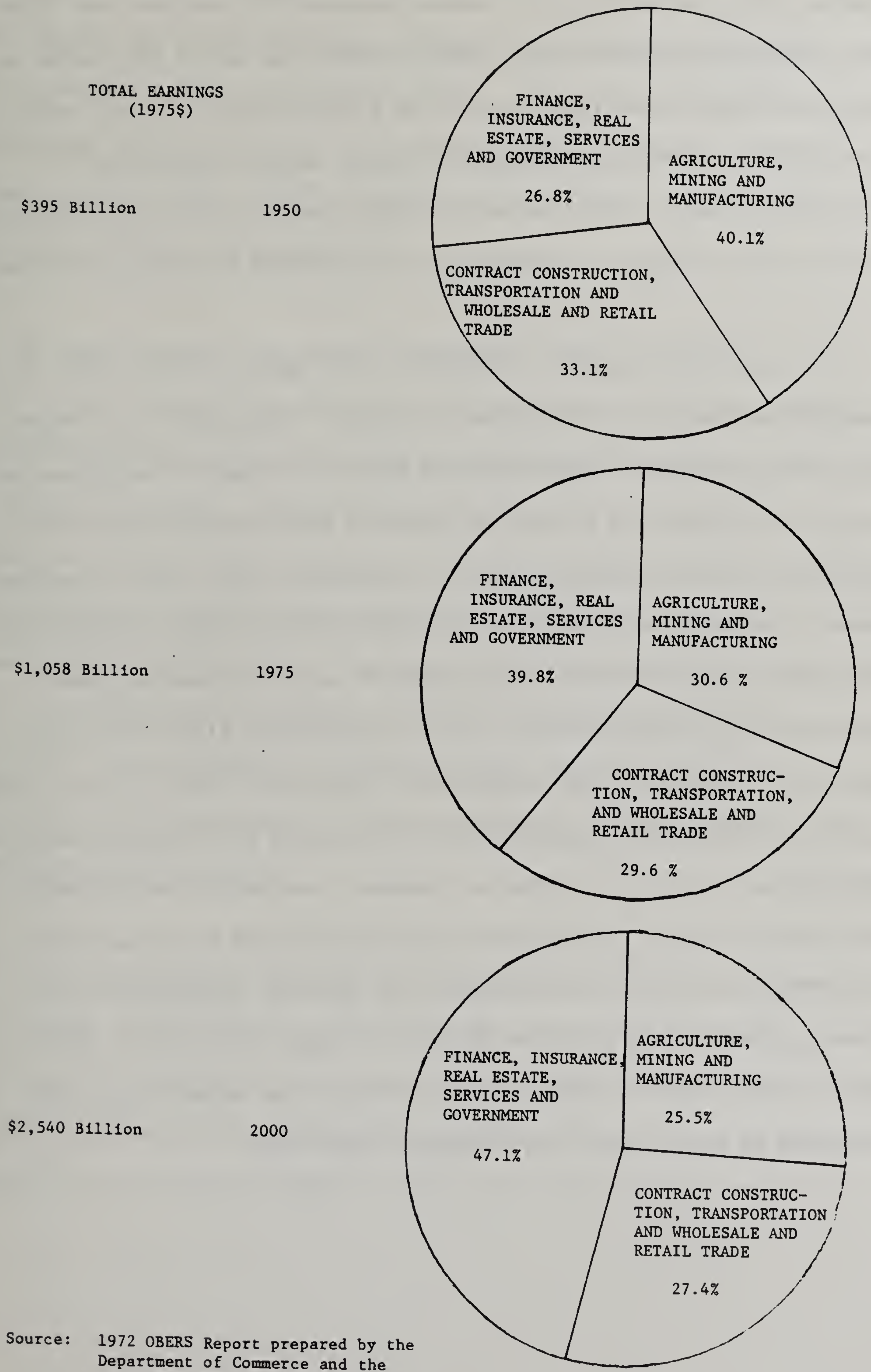
	Per Capita Income				Per Capita Earnings			
	1975	1985	2000	Percent Change 1975-2000	1975	1985	2000	Percent Change 1975-2000
New England	6669	8925	13329	100	5088	6758	10021	97
Mid-Atlantic	7133	9399	13864	94	5620	7364	10816	93
South Atlantic-Gulf	5269	7128	10962	108	4126	5446	8116	97
Great Lakes	6773	9049	13495	99	5522	7263	10646	93
Ohio	5645	7633	11712	108	4490	6001	9084	102
Tennessee	4548	6299	9912	118	3611	4937	7663	112
Upper Mississippi	6218	8317	12529	102	4878	6452	9605	97
Lower Mississippi	4783	6500	10187	113	3722	5008	7763	109
Souris-Red-Rainy	5001	6632	10346	107	3763	4950	7667	104
Missouri	5954	7933	12051	102	4638	6122	9240	99
Arkansas-White-Red	5237	7052	10904	108	3939	5265	8082	105
Texas-Gulf	5802	7778	11792	103	4624	6125	9157	98
Rio Grande	4761	6377	9920	108	3745	4958	7614	103
Upper Colorado	5044	6701	10377	106	3872	5092	7810	102
Lower Colorado	5819	7604	11162	92	4672	6022	8711	87
Great Basin	5628	7544	11465	104	4747	6241	9271	95
Pacific Northwest	5934	8110	12272	107	4613	6238	9335	102
California	6986	9144	13524	94	5453	7057	10314	89
Alaska	7555	9719	14307	89	7010	8765	12450	78
Hawaii	7208	9259	13529	88	5978	7543	10803	81
Caribbean	3225	NC	NC	NC	2514	NC	NC	NC
Total, Regions 1-18	6223	8318	12511	101	4916	6482	9620	96
Total, Regions 1-21	6195	8197	12319	99	4889	6391	9478	94

Total earnings by region are generally consistent with population densities (Figure III-5). The more significant increases in earnings will occur in the South Atlantic-Gulf, Tennessee, Texas-Gulf, Great Basin, and Lower Colorado Regions. Exceptions to the population earnings growth correlations will be in the Alaska and Hawaii Regions where population growth rates will be higher than earnings growth rates, relative to other regions and the national averages. These disparities generally result from differences in the economic activity mixes in each region. Per capita total earnings are usually consistent with per capita incomes and serve as a useful surrogate in assessing water in resource supply, use, and management conditions (Table III-8).

The mix of economic activity in the United States has been shifting from the resource and product-oriented industries toward services in both public and private sectors. In 1950 agriculture, mining, and manufacturing made up about 40 percent of total earnings. By 2000 agriculture, mining, and manufacturing are projected to make up only about one-fourth of total earnings. On the other hand, services and government which made up about 27 percent of total earnings in 1950 had increased to 40 percent of earnings in 1975. The services and government sectors are projected to make up nearly 47 percent of total earnings in the year 2000 (Figure III-6).

However, such shifts in relative shares of the economic activity mix must result from productivity in the basic supporting industries. The dollar earnings in the resource-oriented industries (agriculture,

FIGURE III-6
HISTORICAL AND PROJECTED
DISTRIBUTION OF EARNINGS FOR THE UNITED STATES



Source: 1972 OBERS Report prepared by the Department of Commerce and the U.S. Department of Agriculture manufacturing, and mining) will double between 1975 and the year 2000. Such production increases will greatly affect the use of the Nation's water and related land resources but in different ways. Large reductions in manufacturing withdrawals of water, modest reductions in agricultural uses, and increases in mining uses are projected to result in an overall decline in withdrawals by 15 percent (215 bgd to 184 bgd).

The social and economic condition of the Nation affects both the quantity and quality of the Nation's waters. Increasing real incomes, urbanization, regional migration, and shifts in types of employment and sources of earnings all affect the Nation's water supplies and needs. Generally, all these factors tend to concentrate water uses and waste disposal geographically near the urban population centers and require larger and more accessible reservations of water for instream uses (recreation, fish and wildlife, etc.). Anticipated efficiencies and recycling in manufacturing, agriculture, and steam electric power generation activities will provide opportunities for meeting the changing water use requirements in most of the Nation. However, regions of the Southwest with already critical conditions of water stocks and flows may find increasing cost limitations, perhaps even physical limitations, on economic growth expectations as a result of water scarcities. Other regions, with higher economic projections may find excess capacities developing in water supply and treatment facilities.

Comparison of National and State-Regional Futures

The Second Assessment involves a unique effort to identify and assess the Nation's water resource problems. This effort identifies conditions and problems both at the State-Regional and National levels. This dual approach often reveals differences in outlooks, particularly in the basic economic and social data.

It is important that the Second Assessment present these differences so that users of the data have full benefit of this dual approach in formulating both National and State-Regional resource policies and plans. In most instances, the differences between the National and State-Regional Futures can be traced to basic differences in the economic and social indicator projections, especially popula-tion, earnings, employment, and changing mixes of economic activities. Generally, most regions project greater population growth than the National Future (Table III-9); the exception is the Mid-Atlantic Region. States and regions west of the Mississippi Valley view thier population growth propects with great optimism.

It cannot be expected that any projection will be "right". Because of the inherent uncertainty of projections any plan for development, management, or utilization of water and related land resources should be tested for its sensitivity to changes in economic activity and population. Two courses of action may be taken to help avoid errors in the commitment

Table III-9

TOTAL 1975 POPULATION AND COMPARISON OF PROJECTED INCREASES BETWEEN 1975 AND 2000 FOR NATIONAL AND STATE-REGIONAL FUTURES BY WATER RESOURCES REGION

Region	Population 1975	Increase in Population 1975 to 2000				Regions With Significantly Different Pop. Growth*
		National Future (NF)		State-regional Future (SRF)		
	Millions	Millions	Percent	Millions*	Percent	
New England	12.5	2.8	23	2.6	21	
Mid-Atlantic	39.6	10.3	26	7.9	21	-
South Atlantic-Gulf	25.4	9.3	36	10.6	41	
Great Lakes	30.4	6.0	20	6.0	20	
Ohio	21.2	3.6	17	3.6	17	
Tennessee	3.6	1.1	29	0.9	26	
Upper Mississippi	13.4	2.4	18	2.5	19	
Lower Mississippi	6.4	.7	11	1.6	25	
Souris-Red-Rainy	0.6	-.1	-8	.1	-8	+
Missouri	8.8	1.2	14	2.7	30	+
Arkansas-White-Red	6.8	0.9	14	2.5	34	+
Texas-Gulf	9.9	3.0	30	5.5	53	+
Rio Grande	1.7	0.2	11	1.7	93	+
Upper Colorado	0.3	.0	7	.3	61	+
Lower Colorado	2.4	1.2	50	2.4	89	+
Great Basin	1.3	.5	38	1.1	78	
Pacific Northwest	6.7	.9	13	3.0	34	+
California	21.2	5.9	28	8.2	38	+
Alaska	0.3	.1	43	.6	143	
Hawaii	0.8	.3	38	.5	57	
Caribbean	3.1	1.2	39	1.2	39	
Total, Regions 1-18	212.3	50.0	24	63.0	30	
Total, Regions 1-21	216.4	51.7	24	65.3	30	

* Regions for which the population increase differs by at least 1.5 million people or the percentage growth differs by more than 40%. A plus sign indicates that the SRF is significantly higher than the National Future; a minus sign indicates the opposite.

of resources: first, a more exhaustive analysis may be made to characterize the future more accurately; and secondly, the plan should be kept as flexible as possible to accomodate possible changes in the future course of events.

PART III

CHAPTER 3

WATER REQUIREMENTS FOR DOMESTIC AND COMMERCIAL USES

Perhaps the highest water use priority in the Nation is the assurance of an adequate supply of safe drinking water to satisfy domestic and related requirements. Drinking water supplies are provided by a complex system of municipal, corporate, individual, and other supply systems using surface, ground, catchment, and fresh and saline sources. For much of the Nation the period of readily available, inexpensive, and easily developed water supplies is over. In some areas, gross water use is approaching or already exceeding available supply. In this chapter the issues of quantity, quality, conservation, and reuse of domestic water supplies are considered as a basis for logical management decisions through the year 2000. Decisions on these issues, within the next 25 years, will become increasingly complex as problems are recognized and as it becomes more difficult to meet basic health and sustenance needs for water in the 21st century.

The requirements for domestic water supplies may be considered in two categories: requirements for communities (central systems) and requirements for self-supplied homes and farms (non-central systems). Domestic and related uses are defined primarily as water for such purposes as drinking, bathing, washing, culinary, sanitary flushing (toilet), lawn watering, public service, and fire protection. Most central supplies (community supplies) are referred to as "municipal" water supplies even though ownership of the systems may be by cities and towns or by water districts, counties, and private firms with franchise privileges. Water used for commercial purposes is largely for municipal operations (public buildings, parks, streets, fire protection, etc.) restaurants, hotels, beauty shops, cleaners, florists, and other commercial buildings. Commercial water use is distinct from water used in manufacturing processes as discussed in Chapter 4.

Most of the 29 bgd of water required for domestic and commercial uses is obtained from streams and reservoirs with more than three-fourths of the withdrawals returned to these surface supplies. Only about 7 bgd is used consumptively. However, water for domestic and related uses is obtained from ground water aquifers or combinations of surface and other sources, especially in noncentral systems. Many municipal water systems, regardless of ownership or source of supply, provide directly, or assist in providing, substantial water services for industrial, agricultural, and related non-domestic uses. Domestic water supply is linked to the water demands of manufacturing, agriculture, and energy which are considered separately. Regardless of the sources, system ownership, or related services provided domestic water supplies must meet minimum quality standards required for public health safeguards.

Indirect reuse of water returned to streams, lakes, rivers, and aquifers is a fact of life in many parts of the Nation. However, this indirect reuse is the result of unplanned water use patterns, not by design. A simple cycle of surface and ground water withdrawal, domestic use, and discharge into a watercourse subsequently results in progressive reuse of the water downstream. Much of the discharge, as a result of municipal and industrial water pollution control activities, is currently considered to be innocuous to downstream users. However, biological pollutants, inorganic chemicals, and organic compounds discharged into watercourses or injected into waste-water wells complicate the problem of providing safe drinking water to downstream consumers and threaten future reuse potential of ambient waters.

Questions about the effect of affluent life habits on the quality of surface and ground water are only beginning to be identified. Increases in population and density patterns of populations further complicate the domestic water supply picture, particularly in the face of specific and growing demands for the development of agricultural, industrial, and energy resources. Questions of rights to surface and ground water supplies and the complexities of institutional and jurisdictional arrangements make the situation even more difficult.

Most ground water systems currently provide no treatment prior to distribution within a community. But, most surface water dependent systems provide some level of water treatment prior to community distribution. Treatment by water utilities varies from simple disinfection* of high quality ground water supplies through a full range of treatment processes (including aeration, prechlorination, coagulation, sedimentation, filtration, softening, taste and odor control, iron removal ammoniation, and flouride adjustment). Generally, ground water supplies need less treatment than surface water supplies to provide palatable and aesthetically desirable water.

General Characteristics of Domestic Water Uses

Major factors that influence requirements for municipal and domestic water include size of community, housing density, climate, water price, and income levels of residents. Per capita use of water varies from household to household depending on such factors as size of residential area, water quality, water pressure, price structure, metering, incomes, outdoor uses (swimming pools, gardens, lawns, car washing, etc.), and on institutional factors such as regulations and conservation awareness.

In general, the larger the community the greater the per capita use, particularly if residential density is low. Per capita use tends to be higher in hot, arid climates than in cooler ones because of greater use of water for air conditioning, lawn watering, and swimming pools. In areas with higher per capita income there tend to be greater numbers of water-consuming home appliances than in communities with lower income.

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*Usually chlorination with increasing interest being directed toward ozone and chlorine dioxide disinfection.

It is estimated that a person needs approximately two quarts of water per day either as liquid or in asssociation with solid food to survive. However, typical minimum usage is some two gallons per capita per day.

In the aggregate, including drinking, culinary, washing, and sanitary needs, people served by central systems and pressurized non-central systems average about 87 gallons per capita per day (gcd) for a typical family of four (Table III-10). However, the real average daily domestic withdrawals were 107 gallons per capita per day. The consumptive uses for domestic purposes average 34 gcd, including allowances for leakages and uses not estimated for a typical household. The non-central domestic (rural) use averages about 66 gallons gcd. Interior use for the rural household is about 44 gallons per capita per day while exterior use, including wastes, averages about 22 gcd.

Domestic water use in 1975 accounted for 6.9 percent of all U.S. water withdrawals and 5.9 percent of total water consumption. By the year 2000 domestic uses are expected to use 9.9 percent of all water withdrawn and 6.0 percent of all water consumed. Most domestic water requirements are met by central water supply systems. Central water supply systems currently serve approximately 179 million Americans (83 percent of the people). The remaining 37 million people reside outside the service area of the central water systems with 33 million having their own domestic supplies and approximately 4 million people (less

Table III-10
TYPICAL DAILY DOMESTIC USES OF WATER BY A FAMILY OF FOUR

Types of Household Use	Typical Daily Use: Gallons Per Day Per Family	Typical Daily Use: Gallons Per Day Per Capita
Drinking and water used in kitchen.....	8	2.00
Dishwasher (3 loads per day)..........	15	3.75
Toilet (16 flushes per day)...........	96	24.00
Bathing (4 baths or showers per day)...	80	20.00
Laundering (6 loads per week).........	34	8.50
Automobile washing (2 car-washes per month)..............................	10	2.50
Lawn watering and swimming pools (180 hours per year)................	100	25.00
Garbage disposal unit (1 percent of all other uses)....................	3	0.75
Total......................	346	86.50 *

Source: Southwest Water Works Journal, Vol. 46, No. 12, pg. 18.

*Note: This typical household use cannot be compared directly with the mean per capita withdrawals for total domestic water use of 107 gallons per capita per day (Table III-4, Chapter 1).

than 2 percent) having no running water supply. The number of people served by central water systems has been increasing faster than the growth in population due to the migration of families into urban areas. It is probable that by the year 2000, central water supply systems will be serving nearly 90 percent of the people.

Central Water Supply Systems

In the United States central water supply systems include almost 46,000 separate networks ranging in size from those serving a cluster of houses to some serving more than one million people. The minimum level for designation as a central system is regular service to an average of 25 people or a minimum of 15 service connections. Systems that serve the traveling public are also considered to be part of the public water supply and these noncommunity systems are estimated to number about 200,000 establishments.

The common product of all central water supply systems is potable water although only about one to three percent of the water is used strictly for drinking. The basic production, treatment where necessary, and distribution processes are common to all systems. However, the water supply systems differ in complexity and sophistication because of the varied quality and quantity of water supply sources.

Characteristics of Central Systems

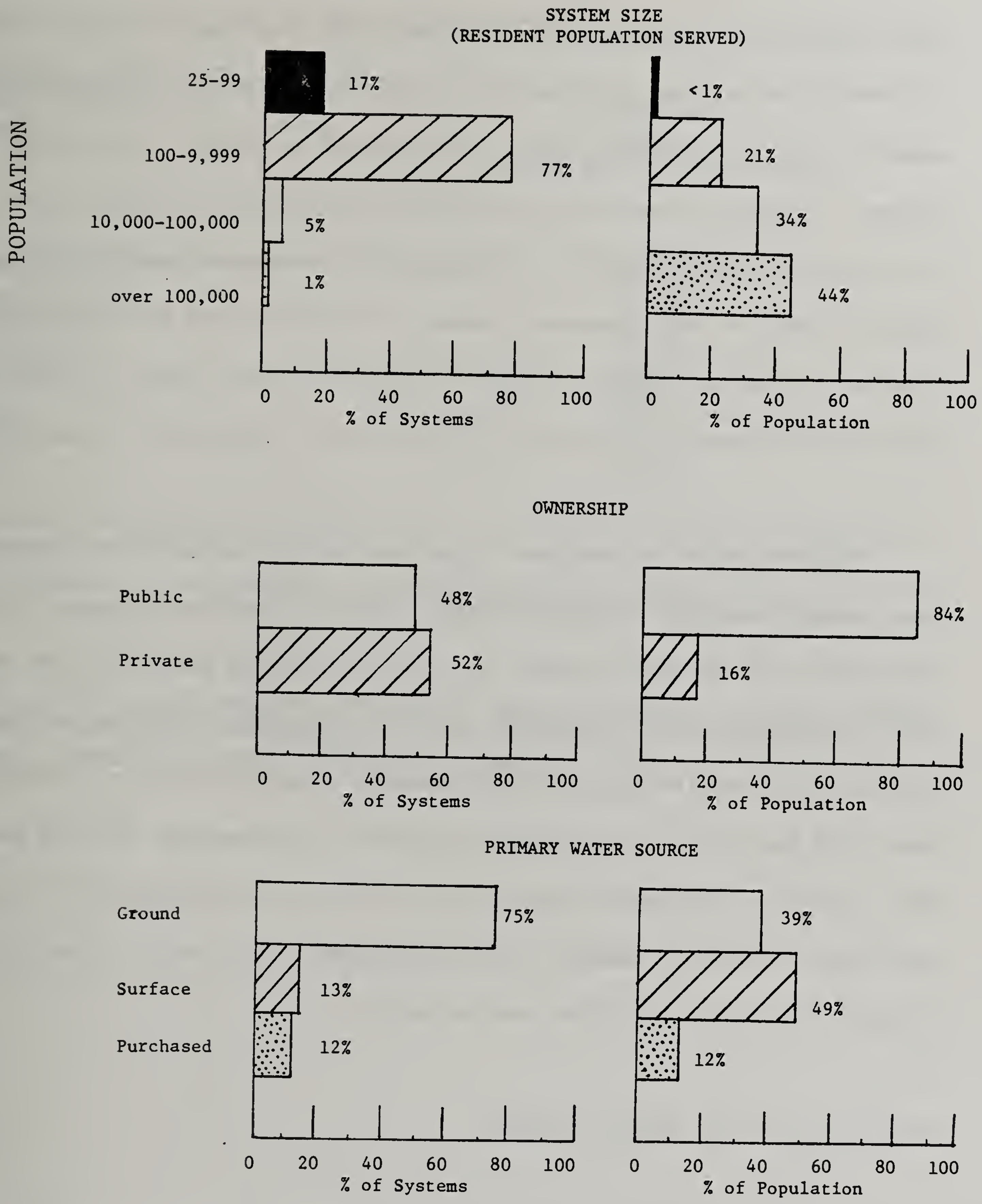
Publicly-owned central water supply systems account for 48 percent of community systems (22,000 systems) and serve 84 percent of the serviced population (Figure III-7). Conversely, investor-owned water utilities comprise 52 percent of the community systems (24,000 systems) but serve only 16 percent of the serviced population.

Generally, investor owned systems serve smaller communities and residential developments. Larger community systems are usually financed through revenue bonds of municipalities which have bond ratings, tax preferences, and tax levying authority. Smaller community systems, especially in rural areas, are likely to be financed through local banks and Federal grants and loans.

Surface water sources constitute only 13 percent of the central water systems but services 49 percent of the population supplied by central systems. Ground water systems comprise 75 percent of all community systems but deliver only 39 percent of the daily water production to the population served by central systems. The remaining 12 percent of the central systems purchase 12 percent of total supplies for retail distribution from other primary producers of domestic supplies in about the same proportions of ground and surface water sources. Ninety-four percent of the community systems serve 10,000 or fewer people and account for only 21 percent of the total population served by community systems.

Figure III-7

NATIONAL PROFILE OF MUNICIPAL WATER SYSTEM CHARACTERISTICS



Note: Total Systems = 45,760; Population Served = 179 million;
Total Daily Water Production = 23,240 MGD.

User Costs For Central Water Supplies

The cost of providing water in community water supply systems is borne largely by the users through some system of user charges. Typical residential water use charges vary considerably among municipalities, based on such factors as degree of treatment provided, age of the system, subsidies from tax sources, or other service charges, and size of the system (Table III-11). Residential customers generally have the highest rates of all customer classes. Municipal and institutional customers classed together appear to pay more than commercial and industrial customers in five out of nine water system size categories.

Implementation of national drinking water standards may increase some average monthly household water bills in the near future. These increases will be quite modest for the more modern and efficient systems now in operation. For more antiquated systems that provide little or no treatment and monitoring, monthly household water bills could rise by about 150 percent for the larger systems to 300 percent for the smaller ones, based on the generalized figures cited in Table III-11. However, such costs are still modest for the assurance that public drinking water is safe from known possible contaminants.

Non-Central Water Supply Systems

Household water supplies are from central systems (public systems or private companies) or self-supplied, non-central systems (individual

Table III-11
AVERAGE RESIDENTIAL WATER RATES, 1975*

Population Range of Water Supply System	Average Rate (Cents per 1,000 gallons)
Over 1 million	53.6
100,000-999,999	65.2
10,000-99,999	71.7
5,000-9,999	79.2
2,500-4,999	93.6
1,000-2,499	85.2
500-999	78.5
100-499	89.0
25-99	73.5

*Note - Based on equivalent of approximately 90 gallons per capita per day for a family of three, with an annual usage of 100,000 gallons per year.

Source: U.S. Environmental Protection Agency, Office of Water Supply, Survey of Operating and Financial Characteristics of Community Water Systems, EPA-570/9-77-03, prepared by Temple, Barker & Sloane, Inc., 1977.

wells or other sources). An individual well is defined as a source that serves five or fewer households (25 people or less). Most individual sources are wells. Other sources include springs, creeks, ditches, rivers, lakes, ponds, cisterns, and other catchments from which individual households obtain water.

Approximately 33 million people, 15 percent of the Nation's population, were served by individual water sources in 1975. By 1985 that number is expected to drop to 34 million, approximately 14 percent of the population. By 2000 only 30 million, or 11 percent of the population, will be serviced from non-central water systems.

Thus, both the number of people and the percentage of total population with individual water sources is expected to drop in the future. Water usage by those with individual sources will tend to rise as a greater proportion of those systems are pressurized. A certain number of households beyond the distribution lines of central systems or those in small rural areas will continue to be served by individual water systems. Individual systems, typical of isolated households, are generally found in use on farms or new housing which central distribution systems have not reached.

Individual systems are particularly vulnerable to contamination and attendant health problems because these supplies are usually used without elaborate disinfection or other treatment. In fact, the typical individual source owner and user is financially unprepared to provide water treatment other than the boiling of drinking water before use. Ground water contamination is particularly insidious. An individual system owner is usually unaware that the water source is contaminated until the health of the users is affected and the cause is traced.

Water Use Projections, Domestic and Commercial

Target years of the First and Second Assessment projections coincided directly only for the year 2000. Total water withdrawal in the conterminous United States by central and non-central systems for domestic and commercial uses in 2000 is projected to be only 37.0 bgd (in the Second Assessment) compared to 53.6 bgd estimated 2000 in the First Assessment. The current estimate for the year 2000 is 16.6 bgd less, 69 percent of the estimate made in the First Assessment. Similarly, consumptive use is currently estimated at 9.4 bgd for the year 2000 compared with the estimate of 18.6 bgd made in the First Assessment. The current estimate of consumptive use for the year 2000 is 9.2 bgd less, 51 percent of the estimate made in the First Assessment.

A change in population growth patterns observed in the 1970 Census resulted in new population growth projections (the OBERS Series E projections). This, in part, may account for the significant reduction in domestic water use figures projected in the two National Assessments (Table III-12).

Current Domestic Requirements

The average United States surface supply of water, based on surface waters in 1970, was more than three times the amount withdrawn and more than 14 times the amount consumed. The projected central and non-central system domestic withdrawals for 2000 are approximately 30 bgd (Table III-12). In addition to surface waters a large volume of fresh water is stored as ground water. An estimated stock of 65 quadrillion gallons (200 billion acre feet) is located beneath the conterminous* United States within a few thousand feet of the surface. Part of this ground water storage can be replenished if tapped. Currently, approximately 69 billion gallons per day (977.3 million acre feet per year) of fresh water is derived from ground water storage for all functional uses. This rate of withdrawal amounts to approximately 20 percent of total withdrawal use (except for hydroelectric use) of water for the United States. Such use is only a small fraction of the ground water development thought possible.

Dependable surface water supplies are highly variable. More confidence can be placed in surface supplies in the Northwest and East, for example, than in the West and Southwest because there is less variation in average annual flows in the humid East than in the arid West.

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* The conterminous 48 States (Regions 1-18) are frequently used as a reference base because of the vast difference in resources involved when Alaska, Hawaii, and Caribbean areas are included.

Table III-12
SUMMARY OF DOMESTIC, COMMERCIAL, AND RELATED WATER USES; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Second Assessment (1975 Data Base)

Type of System	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
Central	21,164	23,983	27,918	4,976	5,665	6,638
Non-Central	2,076	2,297	2,368	1,284	1,394	1,420
Total, Domestic	23,240	26,280	30,286	6,260	7,369	8,058
Total, Commercial	5,530	6,048	6,732	1,109	1,216	1,369
Total, Domestic and Commercial	28,770	32,328	37,018	7,369	8,585	9,427

First Assessment (1965 Data Base)

Type of System	Withdrawals			Consumption		
	1965	1980	2000	1965	1980	2000
Central	23,745	33,596	50,724	5,244	10,581	16,478
Non-Central	2,351	2,474	2,852	1,636	1,792	9,427
Total, Domestic and Commercial	26,096	36,070	53,576	6,880	12,373	18,580

*Note: Commercial uses as defined in the Second National Water Assessment, were included with municipal (public supplied) in the First Assessment.

Similarly, ground water storage in the East and Southeast is a more certain supply for development since replenishment is more likely. Significant annual replenishment is common in the eastern and southeastern portions of the Nation and in other relatively wet areas. In the West and Southwest, where dependable ground water supplies are necessary, replenishment is much slower, often only a small fraction of the amounts withdrawn. Many of the ground water aquifers with very low recharge rates, in comparison to total volume in storage, are in the arid West and southwestern portions of the Nation.

In 1975 only in the Lower Colorado Basin did the amount of fresh water consumed exceed the average annual runoff. This is made possible only by augmentation of the water supply by inflow from the Upper Colorado Basin, importation of other surface waters, repeated withdrawals of the same surface water (reuse), and mining of ground water. Rates of withdrawal exceed 50 percent of the average annual runoff in the Mid-Atlantic Region, the Texas-Gulf Region, the Rio Grande Region, the Upper and Lower Colorado Regions, the Great Basin Region, and the California Region. Such high depletions of stream flows will require increasing attention to managing the supplies and use rates for domestic and commercial purposes in the future.

Future Domestic Requirements

The overall domestic water withdrawal requirements for the conterminous United States are expected to increase approximately 30 percent while consumptive uses will increase by 29 percent by the year 2000, primarily in response to increases in population. The greatest projected increases in water withdrawal usually correspond to the areas forecasting the greatest increases in population. The requirements for the eastern regions tend to correlate closely with population increases for both central and non-central systems (Tables III-13 and III-14 and Figure III-8).

The western regions (particularly the Texas-Gulf, Great Basin, and Lower Colorado) reflect projections of significant increases in both withdrawal and consumptive uses for the domestic sector by 2000. The increase in withdrawals from these regions range from 36 percent in the Texas-Gulf to 56 percent in the Lower Colorado Region. Similar high rates of growth in withdrawals are projected for the South Atlantic-Gulf (56 percent) and the Tennessee Regions (54 percent). High consumptive use rates of greater than 33% (consumption as a percent of withdrawals) are the result of several factors occuring in all of the western Regions except the Pacific Northwest, heavy use of lawn watering in low density residential communities in a naturally arid environment, use of swimming pools, and extensive use of air conditioning. These consumptive rates (and withdrawals) can probably be reduced with appropriate conversation measures.

Consumptive use generally follows the patterns of change in withdrawal requirements. Consumptive use is lowest in the more humid eastern

Table III-13
ESTIMATED DOMESTIC WATER USE IN CENTRAL SYSTEMS - 1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

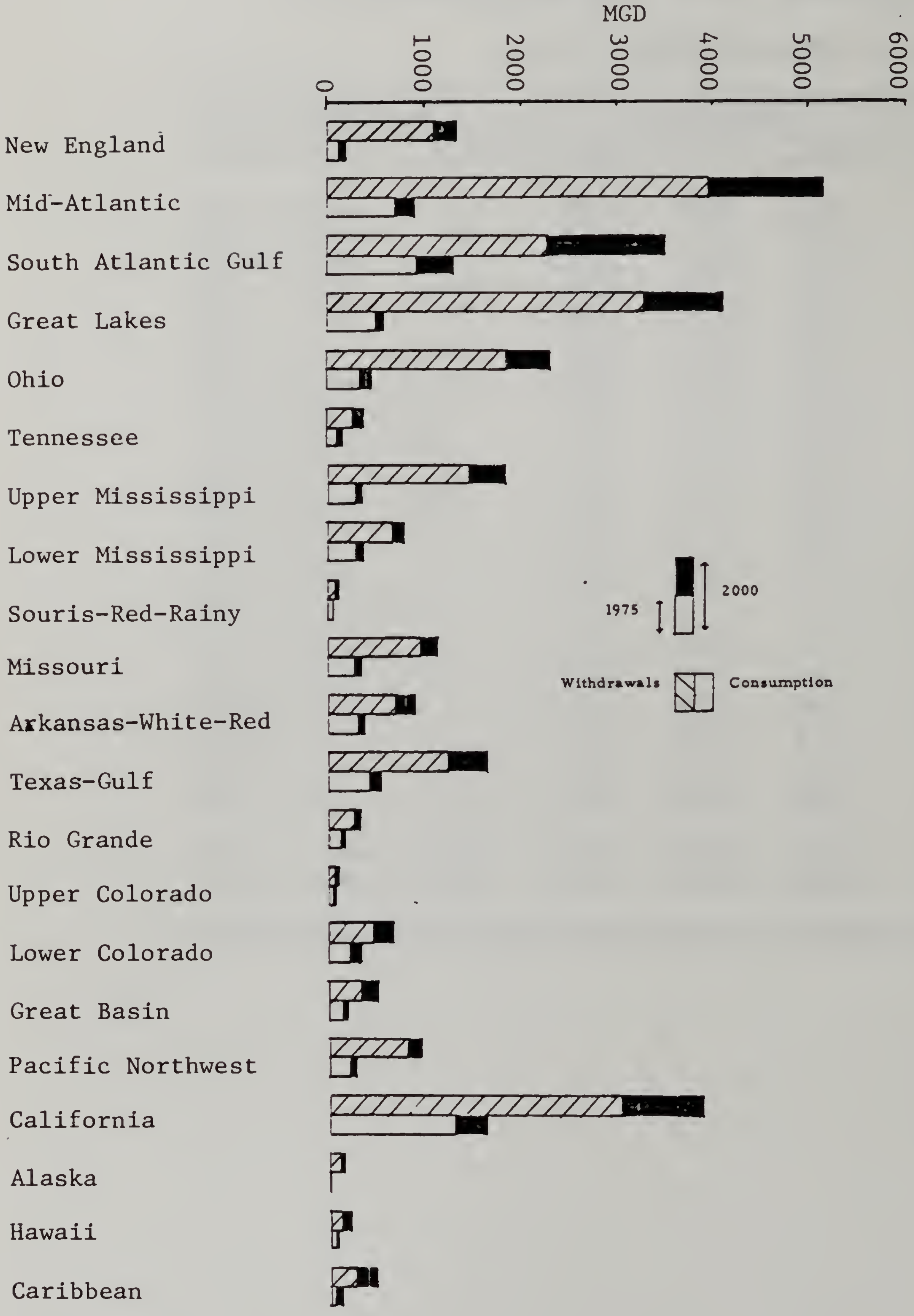
Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	1,011	1,097	1,222	96	103	114
Mid-Atlantic	3,627	4,095	4,758	505	565	650
South Atlantic-Gulf	1,931	2,369	3,005	657	816	1,057
Great Lakes	2,946	3,264	3,717	280	308	349
Ohio	1,561	1,751	2,013	175	196	227
Tennessee	210	259	323	26	32	39
Upper Mississippi	1,280	1,440	1,653	178	200	231
Lower Mississippi	595	657	729	255	279	307
Souris-Red-Rainy	41	44	47	17	18	19
Missouri	872	959	1,083	207	227	256
Arkansas-White-Red	667	737	830	236	262	293
Texas-Gulf	1,152	1,320	1,565	379	431	508
Rio Grande	254	276	301	132	144	158
Upper Colorado	67	73	80	22	24	27
Lower Colorado	416	512	649	195	240	304
Great Basin	333	391	468	126	146	174
Pacific Northwest	720	776	874	157	168	188
California	2,958	3,338	3,839	1,246	1,403	1,611
Alaska	80	101	132	4	5	7
Hawaii	148	172	209	44	52	63
Caribbean	295	352	421	39	46	56
Total, Regions 1-18	20,641	23,358	27,156	4,889	5,562	6,512
Total, Regions 1-21	21,164	23,983	27,918	4,976	5,665	6,638

Table III-14
ESTIMATED DOMESTIC WATER USE IN NON-CENTRAL SYSTEMS - 1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Region	Withdrawal			Consumption		
	1975	1985	2000	1975	1985	2000
New England	111	126	134	68	76	82
Mid-Atlantic	327	372	410	200	225	246
South Atlantic-Gulf	357	432	481	223	263	288
Great Lakes	321	350	360	196	211	214
Ohio	281	317	330	174	193	197
Tennessee	53	60	60	33	37	37
Upper Mississippi	170	169	155	104	102	93
Lower Mississippi	60	64	61	39	40	37
Souris-Red-Rainy	12	12	9	8	7	6
Missouri	89	86	78	55	53	47
Arkansas-White-Red	68	70	64	43	43	38
Texas-Gulf	55	60	56	34	36	33
Rio Grande	11	11	11	7	7	6
Upper Colorado	3	3	3	3	3	2
Lower Colorado	7	8	9	4	5	6
Great Basin	7	8	7	5	5	5
Pacific Northwest	84	87	83	53	52	50
California	56	57	51	33	33	30
Alaska	4	4	5	2	3	3
Hawaii	1	1	1	1	1	1
Caribbean	16	24	33	10	15	19
Total, Regions 1-18	2,072	2,292	2,362	1,282	1,391	1,417
Total, Regions 1-21	2,092	2,321	2,401	1,294	1,409	1,439

Figure III-8
REGIONAL WITHDRAWALS AND CONSUMPTION
OF WATER FOR DOMESTIC USE, 1975 AND 2000
(AVERAGE YEAR)



regions and the Pacific Northwest where projected increases are also much lower than in the arid and semi-arid regions. The requirements for consumptive use in 1975-2000 are expected to increase in the range of 12 to 61 percent in the East and approximately 20 to 56 percent in the West with the Texas-Gulf, Great Basin, Lower Colorado and California Regions exhibiting the highest 29-56 percent) range of increases. It is important to note that these four regions account for almost 40 percent of the water consumed for domestic uses in the Nation. California accounts for 25% by itself.

A particularly large population growth rate is projected for the year 2000 for the Mid-Atlantic, Texas-Gulf, Lower Colorado, Great Basin, and California Regions. In regard to available water supply for all uses, serious problems of excessive withdrawal can be expected in these regions. The most severe problems appear to be centered in the Lower Colorado and Texas-Gulf Regions.

Future Commercial Requirements

Commercial water requirements are closely related to domestic requirements in each region. The principal determinants of commercial water requirements are similar to those for domestic requirements: population density, earnings, climate, and lifestyle. Commercial requirements may be defined as all those municipal and self-supplied waters not used for domestic household and other specified uses such as manufacturing or mineral production. Commercial withdrawals and consumption are expected to increase by 22 percent and 23 percent respectively from 1975 and 2000 (Table III-15). The largest commercial water withdrawals occur in the Great Lakes Region. The largest commercial consumptive uses are expected in California where consumption is about 41 percent of the region's commercial withdrawals. Nationally, commercial water consumption is only about 20 percent of withdrawals.

In summary, population growth patterns, new energy source developments, and environmental pressures on basic water resources are expected to increase existing complications for domestic and commercial water supplies in regions where problems already exist. Deficiencies in the general water supply mean that the problem of providing safe drinking water increases in magnitude and complexity.

Domestic and Commercial Water Quality Problems

Ambient water quality problems are expected to increase with increased urbanization and as the ratio of water withdrawn to average annual flow increases. The trend toward urbanization portends stress on the industrial and energy sectors to produce more goods for an increasingly affluent society. Satisfaction of these new "needs" requires increased quantities of water related to domestic and commercial uses. Where water resources are limited these demands can only be satisfied

Table III-15
ESTIMATED COMMERCIAL WATER USE
ALL SYSTEMS BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Region	Withdrawal			Consumption		
	1975	1985	2000	1975	1985	2000
New England	361	393	442	148	52	58
Mid-Atlantic	650	726	826	91	101	114
South Atlantic-Gulf	553	632	769	118	138	161
Great Lakes	1,010	1,091	1,206	113	123	140
Ohio	495	529	571	62	67	74
Tennessee	90	102	116	11	12	14
Upper Mississippi	515	552	603	63	67	74
Lower Mississippi	150	159	170	49	51	54
Souris-Red-Rainy	15	15	14	6	6	6
Missouri	285	306	336	69	72	78
Arkansas-White-Red	210	221	238	69	72	78
Texas-Gulf	283	317	300	94	103	118
Rio Grande	62	65	68	30	31	32
Upper Colorado	10	10	11	3	4	4
Lower Colorado	75	92	114	35	43	54
Great Basin	38	45	55	17	19	22
Pacific Northwest	274	282	307	55	56	60
California	374	414	470	155	174	198
Alaska	7	9	10	1	2	2
Hawaii	29	36	46	11	12	15
Caribbean	44	52	60	9	11	13
Total, Regions 1-18	5,450	5,951	6,616	1,088	1,191	1,339
Total, Regions 1-21	5,530	6,048	6,732	1,109	1,216	1,369

by greater water reuse. Reuse takes two forms: (1) direct reuse, which means planned and deliberate reuse of treated wastewaters for some beneficial purposes and/or (2) indirect reuse, which occurs when water already used one or more times for domestic or industrial purposes is dscharged into surface or underground waters and used again further downstream.

Indirect use is customary as water (withdrawn from aquifers, lakes, rivers, and streams) is discharged (treated or untreated) for repeated cycles of withdrawal and discharge from upstream to downstream in water courses and pools. Treatment requirements for discharged waters have been established and are enforced, but regulatory actions within themselves are not necessarily efficient or equitable control mechanisms for guaranteeing water quality.

Several Federal regulations for water quality management are now directed toward achieving a National goal of "zero discharge," although some moderation of this level may be introduced in recognition of the costs for this goal. Moreover, toxic substances control laws prohibit the manufacture of new chemicals if they are found to be potentially dangerous to the public health or the environment. But very real threats to downstream and ground water users are posed by runoff and percolation from fields and forests, municipalities, and transportation accidents (truck, rail, and barge); from malfunctions of municipal and industrial waste treatment systems; and from non-point sources and from a plethora of other contaminant sources in modern systems. Further, as towns become cities, a megalopolis pattern develops with less time and distance between points of water discharge and subsequent withdrawal. These growing threats call for an increase in both wastewater and drinking water treatment facilities. But equally necessary are the monitoring and constant alertness for ways to preclude contamination of surface and ground water supplies for both central and non-central supply systems for domestic and commercial requirements.

Comparison of National and State-Regional Futures

For domestic water use there is only a slight difference in estimates for 1975. However, by 2000 the difference in projections is around 8 mgd higher in the State-Regional Future for withdrawals and around 3 mgd higher for consumption. The main reason for these differences is that per capita uses were considered to be higher by some State-Regional study teams. This is particularly true for the California Region which accounts for most of the difference.

PART III

CHAPTER 4

WATER REQUIREMENTS FOR MANUFACTURING AND RELATED USES

In the United States manufacturing was the third largest functional use of water in terms of withdrawals and second largest in terms of consumptive use in 1975. Water intake for manufacturing in 1975 was estimated at an average of about 61 billion gallons per day of fresh and saline waters. Fresh water withdrawals for manufacturing uses in 1975 were 51.2 billion gallons per day or about 15 percent of fresh water withdrawals. Consumption in manufacturing of 6 billion gallons per day was only 5.7 percent of total freshwater consumption.

Manufacturing activities are concentrated in urban areas with nearly 80 percent of earnings from manufacturing derived from establishments in urban areas. Nearly 73 percent of the estimated 1975 earnings from manufacturing were in the six water resources regions of the East. Other industrial concentrations are along the seaboards of the Pacific Ocean and the Gulf of Mexico and along the shoreline of the Mississippi River.

Manufacturing for this Assessment is defined as factories, plants, or mills engaged in the mechanical or chemical transformation of materials, components, or substances into new products. Materials processed by manufacturing plants include products of agriculture, forestry, fishing, mining, petroleum, extraction, and quarrying as well as products of other manufacturing establishments.

More than 312,000 establishments are classified as manufacturing plants in the United States. Although two-thirds are small, with 20 or fewer employees per plant, the trend has been toward larger plants, especially in the more sophisticated process industries. Manufacturing for domestic use or export directly employs some 26 million people and provides the economic base for most urban areas. Manufacturing makes up 27 percent of the GNP and consumes about 39 percent of the total energy in the United States.

Growth in manufacturing earnings is expected to continue at a rate of 3.1 percent annually. By 2000 earnings from manufacturing are estimated at $596 billion, more than twice those of 1975 (Table III-16). The largest portion of the increase will occur in existing industrialized areas, but more rapid rates of industrial growth in the South, Southwest, and Pacific Regions will change the character and extent of water problems of these "sunbelt" areas. The growth in water requirements projected in the Second Assessment is considerably less (in fact a decline in withdrawal is projected) than in the first Assessment (Figure III-9).

Freshwater withdrawals for manufacturing uses by 1985 and 2000 will decline by 54 percent and 62 percent, respectively, from the 51.2 bgd withdrawn in 1975. However, consumption in manufacturing is expected to increase by 47 percent in 1985 and 1943 percent in 2000 as

Table III-16
GROWTH IN POPULATION, EARNINGS, AND FRESHWATER WITHDRAWALS AND CONSUMPTION IN MANUFACTURING 1975, 1985, 2000 (AVERAGE YEAR)

	1975	1985	2000
Population Growth			
Percent Change	- - -	10	23
People (millions)	216	238	268
Total Earnings			
Percent Change	- - -	43	140
Dollars (billion, 1975 $)	1058	1521*	2540*
Earnings from Manufacturing			
Percent Change	- - -	38	113
Dollars (billon, 1975 $)	280	388*	596*
Water Withdrawals by Manufacturing			
Percent Change	- - -	- 54	- 62
(billion gallons per day)	51.2	23.7	19.7
Water Consumption by Manufacturing			
Percent Change	- - -	47	143
(billion gallons per day)	6.0	8.9	14.7

*Note: Does not include Caribbean, Region 21.

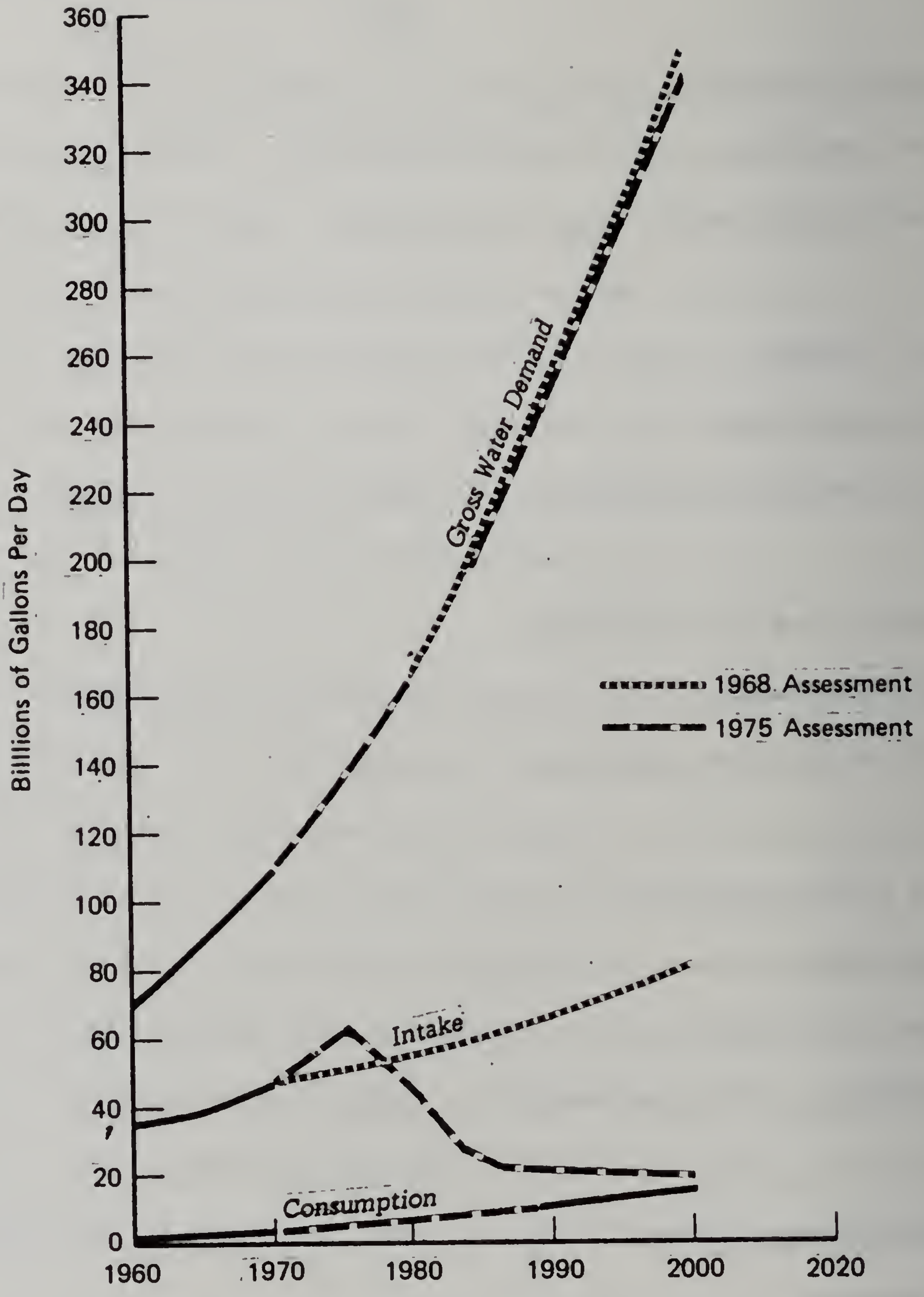


Figure III-9 **USE OF WATER BY THE MANUFACTURING SECTOR**

recycling and reuse rates increase (Table III-16). These recirculation rates vary from about 1.5 times in primary metals manufacturing to 5.1 times in petroleum and coal products refining (Table III-17).

Sources and Uses of Water in Manufacturing

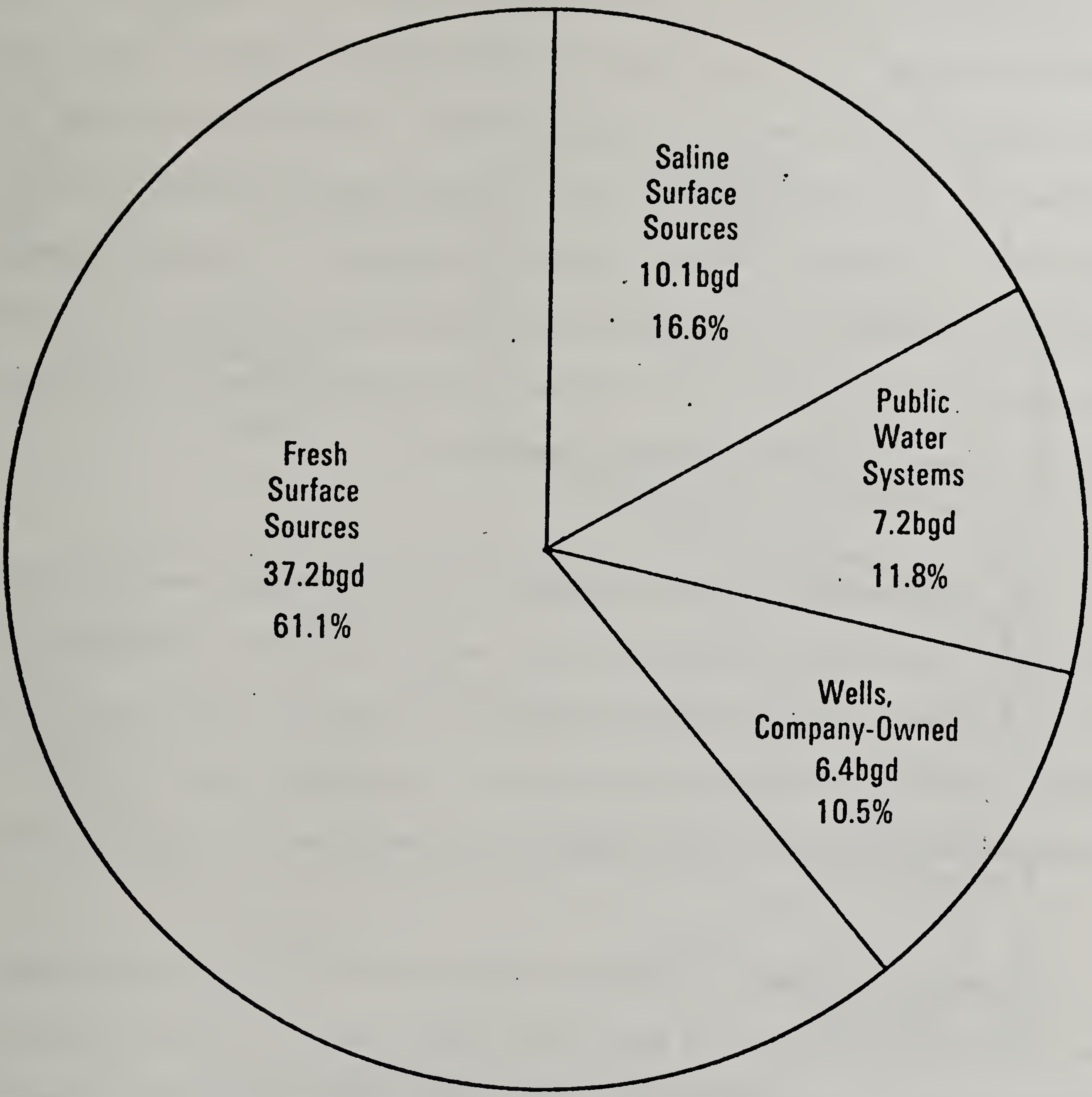
The average daily gross requirement for water by manufacturing in 1975 was estimated at 136.1 billion gallons per day. In order to meet that requirement manufacturing plants withdrew some 51.2 billion gallons per day from fresh water lakes, rivers, and wells; about 7.2 bgd from public water systems, and about 10.1 bgd from saline surface sources for a total withdrawal of 60.9 bgd (Figure III-10).

The remainder, 74.7 bgd, the largest part of the gross water demand, was satisfied by recycling and reusing water and treated effluents within individual plants. The difference between the gross water use and the water intake was accounted for by recirculation of the water an average of 2.2 times in 1975 (Table III-17). The practice of using recycled, treated effluents in place of additional water intake is expanding and is expected to reduce fresh water withdrawals by 62 percent from 51.2 bgd to 19.7 bgd from 1975 to 2000. Three principal uses of manufacturing water are for cooling (69 percent), processing (27 percent), and inplant steam generation (feed water) plus sanitary services (4 percent).

Table III-17
MANUFACTURING WATER USE BY INDUSTRY, 1975

Industry	Total Water Intake* (bgd)	Recirculation Ratio	Gross Water Use (bgd)
Chemical and Allied Products	18.8	2.1	39.4
Primary Metals	16.5	1.5	25.0
Paper and Allied Products	8.7	2.9	25.7
Petroleum and Coal Products	4.3	5.1	21.9
Food and Kindred Products	3.6	1.6	5.7
Transportation Equipment	1.8	2.6	4.7
Textile Mill Products	.7	2.8	2.1
All Other Manufacturing	6.5	1.8	11.6
National Average	60.9	2.2	136.1

* Includes brackish and saline water.



Total Water Intake=60.9 bgd*

Figure III-10

Sources of Water Intake for Manufacturing, 1975

*For the conterminous United States, Regions 1-18.

Water for Cooling

Approximately 69 percent (94.5 bgd) of the water requirements for manufacturing is for cooling and condensing (Figure III-11). Physical and chemical operations are energy-intensive; the power being used to provide heat for chemical reaction; to improve the malleability of materials; to generate steam; to operate equipment; to maintain temperature and humidity of the working environment; and to convert or contain the gaseous, liquid, and solid residuals of manufacturing in compliance with stringent pollution control regulation.

The large amount of cooling water is used to manage heat, to maintain operating temperatures within critical ranges, to protect equipment, for air conditioning, and to speed production processes by reducing cooling times between steps in plant operations. The cooling water is physically separated from materials and products in these manufacturing applications.

Cooling water temperatures are increased 15 to 25 degrees through heat exchanger surfaces and such heated waste must be cooled by mechanical heat transfers through evaporation in cooling towers or other heated air exchangers. Direct discharge of heated cooling water to surface waters is increasingly restricted by water pollution control requirements which encourage recycling of cooling waters within the manufacturing facility.

Some manufacturing plants in coastal areas with large cooling water needs are withdrawing large volumes of saline water from bays and estuaries

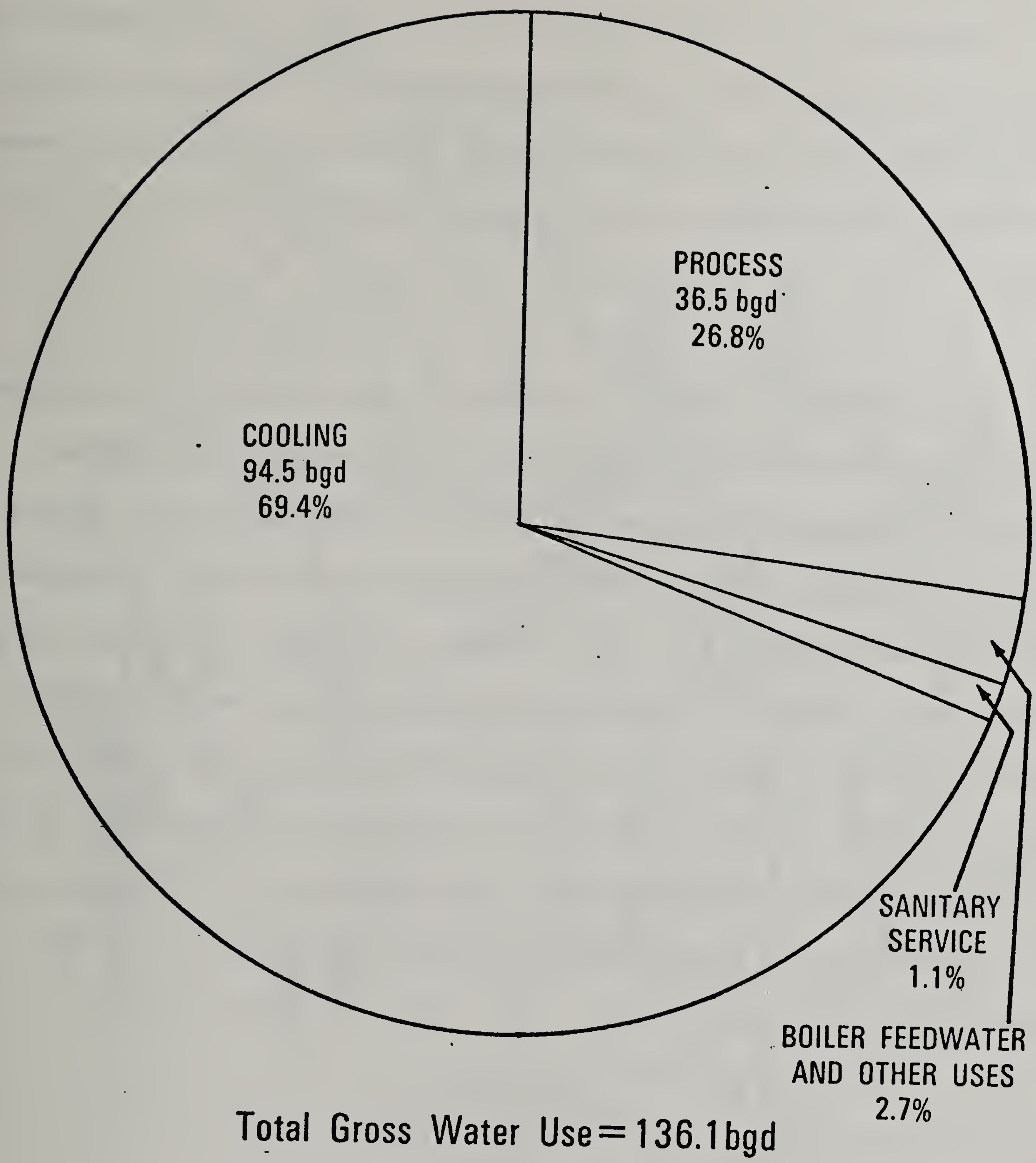


Figure III-11
Uses of Water in Manufacturing, 1975

and discharging the heated effluents back to coastal waters (Figure III-12). It is expected that such discharges of heated saline waters into ecologically sensitive estuaries will be restricted in the future under the Federal Water Pollution Control Act Amendments of 1972 (P. L. 92-500).

It is further assumed that such use of saline water will have been totally abandoned by the year 2000 in favor of more cost-effective fresh water systems that permit recycling at very high rates. Figure III-12 is a display of the water resources regions in which saltwater use occurred in 1975. The total volumes of saltwater withdrawn, and the percentage of the total water withdrawal requirement satisfied with saltwater in each region is shown where it was used. The largest saltwater withdrawals, three-fourths of the national total, are made in the Texas-Gulf and Mid-Atlantic Regions. The highest ratio of saltwater use to freshwater use in manufacturing (93 percent) occurred in the Rio Grande Region.

Water for Processing

Process water is used directly in manufacturing and accounts for 27 percent (36.5 bgd) of the gross water requirement for manufacturing. Process water, as defined for the National Assessment, is water which comes into direct contact with the materials that are processed, some of which may remain in the intermediate and final products.

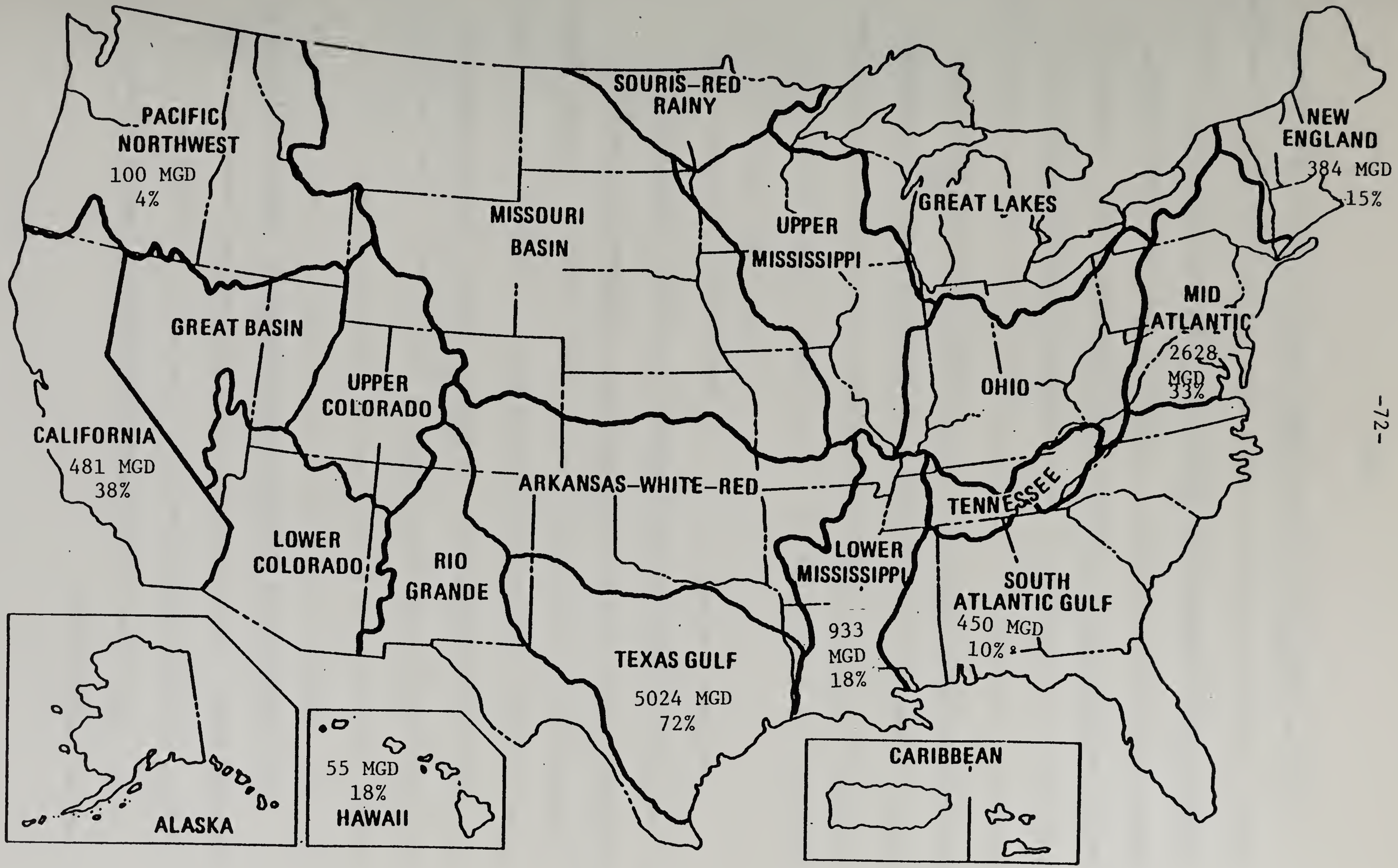

PACIFIC NORTHWEST
100 MGD
4%
CALIFORNIA
481 MGD
38%
GREAT BASIN
UPPER COLORADO
LOWER COLORADO
RIO GRANDE
MISSOURI BASIN
SOURIS-RED RAINY
ARKANSAS-WHITE-RED
TEXAS GULF
5024 MGD
72%
UPPER MISSISSIPPI
LOWER MISSISSIPPI
933
MGD
18%
GREAT LAKES
OHIO
TENNESSEE
SOUTH ATLANTIC GULF
450 MGD
10%
MID ATLANTIC
2628
MGD
33%
NEW ENGLAND
384 MGD
15%
ALASKA
55 MGD
18%
HAWAII
CARIBBEAN

Figure III-12
SALT WATER WITHDRAWALS FOR MANUFACTURING
AND PERCENTAGE OF TOTAL MANUFACTURING WITHDRAWALS BY WATER
RESOURCES REGIONS, 1975

With few exceptions, the processed materials are to some degree soluble in water. The process water often enters the mixture of materials employed in the manufacturing process. In addition, the high density of water, combined with turbulence, results in the suspension of non-soluble solid and liquid materials in the process water. In many operations it is possible to use process water several times, but eventually the quality is so changed that the water must be removed from the manufacturing operations. It is at this point that the process water becomes the industrial waste effluent that must be treated and improved in quality to meet the standards set by water pollution control agencies.

Standards have been set for most manufacturing effluents, and eventually standards will be promulgated for all. Judging by the standards set to date and the probability of higher standards for effluent quality in the future, it is likely that the treatment technology to be used will cleanse process waste water to a quality level suitable for reuse and recycling in the industrial plant. In many cases, the cleansed effluents will be of equal or better quality than the original water.

Cost savings from the reuse and recycling of treated effluents can be substantial. It can be anticipated that treated process water recycling even more widely practiced in industry in the future. As a result, withdrawals of fresh and saline water for process use will decline substantially.

Other Manufacturing Uses--Feedwater and Sanitation

The remaining 4 percent (5.1 bgd) of gross water demands for manufacturing are for personal and sanitary uses (about 1.5 bgd), for steam generation (boiler feedwater), and for miscellaneous uses in factory buildings and grounds.

The demand for boiler feedwater to generate steam in manufacturing plants is estimated at 2.7 billion gallons per day in 1975. Approximately one half of that volume was newly withdrawn from freshwater supply sources, and the remainder was recycled from various operations in the manufacturing plants.

Miscellaneous uses of water for groundskeeping, fire control, and the like account for the small remaining portion of total manufacturing water demand.

Manufacturing Water Use Projections

The 312,000 establishments classified as manufacturers under the Standard Industrial Classification (SIC) system represent a wide and diversified range of operations and products. Many manufactures (such as those engaged in apparel, printing, and publishing) use relatively little water while others (such as petroleum refineries, paper processing, and textile finishing) require vast quantities.

The consumptive use of water is forecast by utilizing coefficients linked to the gross water demands of the industries that comprise the sector. The coefficients are derived from the individual plant water use information (1970 data) but are modified for the year 2000 by judgmental analyses of the increases in consumption that might result from advanced waste treatment practices thought likely to be adopted.

Regional Distribution of Manufacturing Water Requirements

The estimates and projections of withdrawals and consumptive uses of fresh water by manufacturers for 1975, 1985, and 2000 indicate the relative changes in manufacturing technologies to conserve water in the various water resources regions (Table III-18). The volume of saline water withdrawal (10.1 bgd in 1975) is expected to decline substantially relative to fresh water withdrawals. All projections indicate total withdrawal requirements will be from fresh water by 2000.

In 1975 two regions, Great Lakes and Ohio, withdrew for manufacturing uses an average of 24.1 bgd, about 47 percent of total manufacturing withdrawals of fresh water. Consumption in these two regions was 2.3 bgd or about 38 percent of manufacturing consumption of freshwater.

Table III-18

ESTIMATED FRESHWATER WITHDRAWALS AND CONSUMPTION BY MANUFACTURING INDUSTRIES BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR (MILLION GALLONS PER DAY)

Region	Withdrawal			Consumption		
	1975	1985	2000	1975	1985	2000
New England	2,169	1022	783	192	331	563
Mid-Atlantic	5,416	2,525	1,942	606	935	1,358
South Atlantic-Gulf	4,105	3,371	3,316	612	1,206	2,533
Great Lakes	13,218	4,105	2,821	1,472	1,719	2,056
Ohio	10,879	3,322	2,342	816	1,091	1,758
Tennessee	2,094	764	670	148	266	514
Upper Mississippi	2,029	882	727	239	308	508
Lower Mississippi	4,159	1,634	1,363	314	551	1,067
Souris-Red-Rainy	102	43	31	13	18	23
Missouri	668	312	292	134	120	202
Arkansas-White-Red	714	476	478	165	233	358
Texas-Gulf	1,931	2,560	2,443	572	1,003	1,915
Rio Grande	19	41	32	5	15	24
Upper Colorado	4	2	2	2	1	2
Lower Colorado	87	90	138	54	54	103
Great Basin	112	92	98	24	42	76
Pacific Northwest	2,324	1,320	1,130	325	501	880
California	796	829	828	257	370	567
Alaska	133	93	86	25	41	67
Hawaii	251	181	139	74	88	112
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	50,826	23,390	19,436	5,950	8,764	14,507
Total, Regions 1-21	51,210	23,664	19,661	6,049	8,893	14,686

However, by year 2000 these two heavily industrialized regions are expected to withdraw only 5.2 bgd, about 26 percent of the national total. This represents a 78 percent reduction of water withdrawals from 1975 to 2000 in the industrial Great Lakes and Ohio Regions versus 61 percent nationally. Consumption in manufacturing in 2000 in the Great Lakes and Ohio Regions will be 3.8 bgd, again about 25 percent of the national total consumption.

Reuse of manufacturing water in the Great Lakes and Ohio Regions will be 73 percent of the waters withdrawn will be consumptively used in 2000. By 2000 the largest withdrawals of freshwater for manufacturing is expected to be in the South Atlantic-Gulf region at 3.3 bgd or 17 percent of the national total.

Projections by Manufacturing Sector and Region

The critical water requirements for manufacturing can be more accurately assessed by analyzing the projected requirements for each major sector to include the regions in which these uses are dominant. In the Second Assessment eight manufacturing sectors were identified with respect to their projected water withdrawal and consumption requirements. These sectors, and their proportion of total manufacturing water requirements in 1975, are: primary metals (34 percent of withdrawals, 18 percent of consumption); chemicals (26 and 27 percent); paper and products (17 and 27 percent); food and kindred products (5 and 6 percent); petroleum refining (5 and 6 percent); transportation manufacturing (3 and 2 percent); textile mile products (1 and 1 percent); and all other manufacturing (9 and 13 percent). Primary metals now have high withdrawals relative to consumption and a very low recirculation ratio.

Water requirements for primary metals manufacturing are highest in the Ohio and Great Lakes Regions where 78 percent of the total withdrawals for this use were projected for 1975. These regions will continue to require more water for this sector of the economy through 2000 (Table III-19). The ratio of consumption to withdrawal in 1975 was twice as much in the Great Lakes (14 percent) as in the Ohio Region (7 percent).

Chemicals manufacturing is less concentrated geographically than primary metals. However, the Ohio Region is the leading user of water for chemical manufacturing at 3.3 bgd in 1975 or nearly one-fourth of the national total (Table III-20). Other regions with high water requirements for chemicals manufacturing include the Lower Mississippi (2.3 bgd, 17 percent); the Great Lakes (1.9 bgd, 14 percent); the Mid-Atlantic (1.9 bgd, 14 percent); and the Tennessee Region (1.5 bgd, 11 percent).

Table III-19

SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN PRIMARY METALS MANUFACTURING BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	132	36	20	4	8	14
Mid-Atlantic	1124	616	365	173	239	288
South Atlantic-Gulf	270	189	145	51	73	115
Great Lakes	7445	2212	1282	1030	1069	1017
Ohio	6346	1833	1050	467	607	834
Tennessee	77	43	33	12	16	25
Upper Mississippi	315	135	95	41	41	75
Lower Mississippi	535	101	58	29	36	46
Souris-Red-Rainy	0	0	0	0	0	0
Missouri	89	23	14	8	10	11
Arkansas-White-Red	137	84	62	18	29	49
Texas-Gulf	588	242	162	60	99	129
Rio Grande	10	6	4	1	2	3
Upper Colorado	0	0	0	0	0	0
Lower Colorado	13	8	6	12	3	5
Great Basin	75	65	68	12	26	54
Pacific Northwest	281	89	55	20	29	43
California	34	32	32	13	18	24
Alaska	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	17571	5714	3451	1951	2305	2732
Total, Regions 1-21	17571	5714	3451	1951	2305	2732

Table III-20

SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN CHEMICALS MANUFACTURING BY WATER RESOURCES REGIONS – 1975, 1985, 2000; AVERAGE YEAR (MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	109	66	55	15	27	42
Mid-Atlantic	1850	686	568	179	301	429
South Atlantic-Gulf	870	668	748	165	317	589
Great Lakes	1939	425	335	71	131	255
Ohio	3261	745	593	168	215	464
Tennessee	1520	396	336	81	145	262
Upper Mississippi	384	143	131	54	61	99
Lower Mississippi	2251	734	635	141	264	504
Souris-Red-Rainy	0	0	0	0	0	0
Missouri	188	83	88	68	35	69
Arkansas-White-Red	162	94	102	43	63	81
Texas-Gulf	586	1490	1448	271	549	1151
Rio Grande	1	31	22	0	10	17
Upper Colorado	0	0	0	0	0	0
Lower Colorado	8	7	13	5	5	9
Great Basin	14	5	5	2	3	4
Pacific Northwest	260	73	65	30	42	49
California	51	69	82	21	37	61
Alaska	4	4	5	2	3	4
Hawaii	0	0	0	0	0	0
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	13454	5715	5226	1314	2205	4085
Total, Regions 1-21	13458	5719	5231	1316	2208	4089

These five regions withdraw 10.8 bgd (80 percent of the total) for chemicals manufacturing. The ratio of consumption to withdrawal requirements in chemicals manufacturing in 1975 was about the same as primary metals, 10 percent as a national average. However, in the Ohio region consumption is only 5 percent of the withdrawals for chemicals manufacturing.

The paper manufacturing sector is a heavy user of water in the South Atlantic-Gulf and Pacific Northwest Regions where 2.1 bgd (25 percent) and 1.3 bgd (16 percent) of the withdrawals are concentrated (Table III-21). The New England, Mid-Atlantic, and Great Lakes Regions are also heavy users of water for paper and allied products manufacturing at rates of 1.0 bgd, 0.7 bgd, and 1.0 bgd respectively. These five regions collectively withdraw 5.1 bgd or 62 percent of the water withdrawn by the paper manufacturing sector.

The largest withdrawals for food and kindred products in 1975 occurred in the Upper Mississippi Region, which withdrew more than 20 percent of the total for this sector (Table III-22). The Mid-Atlantic, Great Lakes, and Hawaii Regions are also a relatively large user of water for this activity. Generally withdrawals for food processing are widely dispersed among the regions with consumption averaging about 15 percent of withdrawals.

Table III-21
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN PAPER MANUFACTURING BY WATER RESOURCES REGIONS
1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	962	520	395	86	158	313
Mid-Atlantic	745	460	389	76	146	305
South Atlantic-Gulf	2111	1974	1875	262	614	1492
Great Lakes	982	534	427	143	213	334
Ohio	224	151	133	23	46	101
Tennessee	381	268	246	41	85	196
Upper Mississippi	348	140	104	20	38	80
Lower Mississippi	517	403	381	46	119	304
Souris-Red-Rainy	86	33	22	9	13	17
Missouri	2	3	5	0	1	4
Arkansas-White-Red	200	125	110	30	50	86
Texas-Gulf	245	200	218	38	79	174
Rio Grande	0	0	0	0	0	0
Upper Colorado	0	0	0	0	0	0
Lower Colorado	15	18	26	3	8	22
Great Basin	0	0	0	0	0	0
Pacific Northwest	1326	868	739	197	312	588
California	170	212	228	60	101	178
Alaska	124	86	78	24	37	62
Hawaii	0	0	0	0	0	0
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	8214	5909	5298	1034	1983	4194
Total, Regions 1-21	8438	5995	5376	1058	2020	4256

Table III-22

SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN FOOD AND KINDRED PRODUCTS BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR (MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	56	30	23	9	11	15
Mid-Atlantic	271	172	130	45	61	78
South Atlantic-Gulf	142	99	91	15	28	59
Great Lakes	354	153	116	38	48	68
Ohio	124	71	56	17	24	34
Tennessee	19	10	8	1	2	5
Upper Mississippi	506	234	169	62	81	118
Lower Mississippi	209	104	71	17	29	52
Souris-Red-Rainy	15	10	8	4	5	5
Missouri	187	113	92	23	36	65
Arkansas-White-Red	54	28	25	7	9	15
Texas-Gulf	66	55	54	11	21	38
Rio Grande	0	0	0	0	0	0
Upper Colorado	0	0	0	0	0	0
Lower Colorado	19	10	8	14	4	6
Great Basin	10	9	8	3	5	6
Pacific Northwest	112	68	56	11	19	41
California	189	146	122	41	59	81
Alaska	0	0	0	0	0	0
Hawaii	246	174	132	70	83	106
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	2233	1312	1037	318	442	686
Total, Regions 1-21	2579	1486	1169	388	525	792

Water withdrawals for petroleum refining are concentrated in the Great Lakes (27 percent), the Mid-Atlantic (22 percent), the Lower Mississippi (17 percent), and the Texas-Gulf (12 percent) Regions. These four regions account for two bgd of withdrawals for petroleum refining or 79 percent of the total (Table III-23). Consumptive use in the petroleum refining sector averaged about 22 percent of withdrawals in 1975.

Transportation equipment manufacturing water requirements are concentrated in two regions, the Ohio with nearly one-half the total and New England with one-fourth of the withdrawals (Table III-24). Textile finishing and manufacturing is highly concentrated in the South Atlantic-Gulf Region where 76 percent of total withdrawals for this activity occur (Table III-25). Manufacturing water requirements for all other industries are concentrated in the industrial areas of the Nation--the Great Lakes (22 percent), the Mid-Atlantic (16 percent), the Ohio (15 percent), and New England (11 percent). Consumption, as a proportion of withdrawals for all other manufacturing in 1975 averages about 12 percent (Table III-26).

Table III-23
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN PETROLEUM REFINING BY WATER RESOURCES REGIONS 1975, 1985, 2000; AVERAGE YEAR (MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	16	8	5	3	4	4
Mid-Atlantic	562	228	137	71	87	109
South Atlantic-Gulf	28	32	25	12	15	20
Great Lakes	687	141	95	51	56	74
Ohio	114	52	48	23	27	38
Tennessee	0	0	0	0	0	0
Upper Mississippi	50	36	33	18	19	26
Lower Mississippi	441	220	150	66	80	119
Souris-Red-Rainy	0	0	0	0	0	0
Missouri	91	36	29	20	19	24
Arkansas-White-Red	74	75	94	44	51	75
Texas-Gulf	312	496	479	170	224	382
Rio Grande	0	0	0	0	0	0
Upper Colorado	4	1	1	2	0	1
Lower Colorado	1	1	0	1	0	0
Great Basin	8	7	7	4	4	6
Pacific Northwest	11	12	15	6	8	13
California	123	147	100	57	64	79
Alaska	1	1	1	0	0	1
Hawaii	5	6	6	3	4	5
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	2522	1492	1218	548	658	970
Total, Regions 1-21	2528	1499	1225	551	662	976

Table III-24

SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN TRANSPORTATION EQUIPMENT MANUFACTURING BY WATER RESOURCES REGIONS - 1975; 1985, 2000; AVERAGE YEAR (MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	341	97	61	26	37	48
Mid-Atlantic	67	46	32	6	15	24
South Atlantic-Gulf	19	14	34	4	17	26
Great Lakes	657	273	204	80	111	155
Ohio	89	75	70	21	32	55
Tennessee	0	0	0	0	0	0
Upper Mississippi	26	23	22	5	9	16
Lower Mississippi	3	3	3	1	1	2
Souris-Red-Rainy	0	0	0	0	0	0
Missouri	7	8	9	3	4	7
Arkansas-White-Red	0	0	0	0	0	0
Texas-Gulf	89	24	15	6	9	12
Rio Grande	0	0	0	0	0	0
Upper Colorado	0	0	0	0	0	0
Lower Colorado	10	8	7	5	6	5
Great Basin	0	0	0	0	0	0
Pacific Northwest	0	0	0	0	0	0
California	25	24	22	4	8	16
Alaska	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	1333	595	479	161	249	366
Total, Regions 1-21	1333	595	479	161	249	366

Table III-25
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN TEXTILE MANUFACTURING BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	45	12	5	2	4	4
Mid-Atlantic	37	17	12	3	5	7
South Atlantic-Gulf	427	200	157	50	68	107
Great Lakes	0	0	0	0	0	0
Ohio	7	4	3	1	1	2
Tennessee	31	21	19	8	11	14
Upper Mississippi	0	0	0	0	0	0
Lower Mississippi	13	10	11	1	4	8
Souris-Red-Rainy	0	0	0	0	0	0
Missouri	0	0	0	0	0	0
Arkansas-White-Red	1	2	5	1	1	3
Texas-Gulf	0	0	0	0	0	0
Rio Grande	0	0	0	0	0	0
Upper Colorado	0	0	0	0	0	0
Lower Colorado	0	0	0	0	0	0
Great Basin	0	0	0	0	0	0
Pacific Northwest	0	0	0	0	0	0
California	0	0	0	0	0	0
Alaska	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	561	266	212	66	94	145
Total, Regions 1-21	561	266	212	66	94	145

Table III-26
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN ALL OTHER MANUFACTURING BY WATER RESOURCES REGIONS 1975, 1985, 2000 ; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	507	253	219	47	82	123
Mid-Atlantic	760	300	309	53	81	118
South Atlantic-Gulf	238	195	241	53	74	125
Great Lakes	1054	367	362	59	91	153
Ohio	714	391	389	96	139	230
Tennessee	66	26	28	5	7	12
Upper Mississippi	400	171	173	39	59	94
Lower Mississippi	190	59	54	13	18	32
Souris-Red-Rainy	1	0	1	0	0	1
Missouri	104	47	55	12	15	22
Arkansas-White-Red	85	68	80	22	30	49
Texas-Gulf	45	52	67	16	22	29
Rio Grande	8	4	6	4	3	4
Upper Colorado	0	1	1	0	1	1
Lower Colorado	21	38	78	14	28	56
Great Basin	5	6	10	3	4	6
Pacific Northwest	343	210	200	61	91	146
California	204	199	242	61	83	127
Alaska	4	2	2	0	0	0
Hawaii	0	1	1	1	1	1
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total, Regions 1-18	4736	2387	2515	558	828	1328
Total, Regions 1-21	4740	2390	2518	559	829	1329

Comparison of National and State-Regional Futures

In the final stages of the National Assessment, State-Regional study teams and Federal agency staff attempted to reconcile the differences between the NF and SRF data bases and projections with considerable success. Significant differences still remain, notably in the projections for the Mid-Atlantic, South Atlantic-Gulf, Tennessee River, Lower Mississippi, and Pacific Northwest Regions. In those regions the primary reasons for the differences were related to the rate of assumptions about rates of growth in regional manufacturing and adoption of recycling of treated effluents. Overall, manufacturing requirements for fresh water should be attained through recycling and improved waste treatment processes to meet projected needs in all regions.

PART III

CHAPTER 5

FOOD AND FIBER PRODUCTION AND RELATED RESOURCE CONSIDERATIONS

Production of food and fiber places a greater demand on total water resources than any other sector of the United States economy. Irrigation is the major water withdrawal use -- more than 159 billion gallons per day or 46 percent of all water withdrawals in 1975 (Table III-27). Growth in world population and increases in demand for United States food and fiber products over the next 25 years will require astute management of agriculture water uses to meet domestic and export needs.

Some 83 percent of all fresh water consumed from ground and surface sources is due to irrigate crops and water livestock. This high consumptive use in agriculture, amounts to 56 percent of the quantities of water withdrawn for irrigation. Consumption in food and fiber production is expected to continue to increase to the year 2000, but increased irrigation efficiencies will reduce withdrawals slightly.

In addition to heavy use of water, agriculture and forestry have a significant effect on the quality and quantity of water available for other uses. For example, pesticides affect the quality of water, and ground and crown cover influences the time and amount of water retained in the soil or in subsurface aquifers or released to surface streams and reservoirs.

Table III-27
SUMMARY OF WATER WITHDRAWAL AND CONSUMPTIVE USE RELATIONSHIPS BY WATER USE SECTOR, 1975; AVERAGE YEAR

Type of User	Withdrawals		Consumption		Consumption as a percent of withdrawals
	bgd	percent	bgd	percent	
Agriculture					
Irrigation	158.7	46	86.4	81	55
Livestock	1.9	1	1.9	2	100
Steam Electric Generation	88.9	26	1.4	1	2
Manufacturing	51.2	15	6.0	6	12
Domestic and Commercial	28.8	9	7.4	7	26
Minerals	7.1	2	2.2	2	31
Other	1.9	1	1.3	1	72
Total, Regions 1-21	338.5	100	106.6	100	32

Estimates of future resource uses are also affected by policy assumptions in such areas as conservation, energy, and the environment. Resource capacities are evaluated in terms of estimates of future uses and management methods. Application of policy alternatives results in varied estimates of crop and timberland production capacities, water use requirements, land development, and food prices. Also taken into account are uncertainties resulting from change in production technology which, in turn, influence levels of capital requirements, land management practices, fertilizer use, and land development.

Future uses of water food and fiber production and the consequences of agricultural uses on the quantity and quality of remaining supplies will be influenced by three factors:

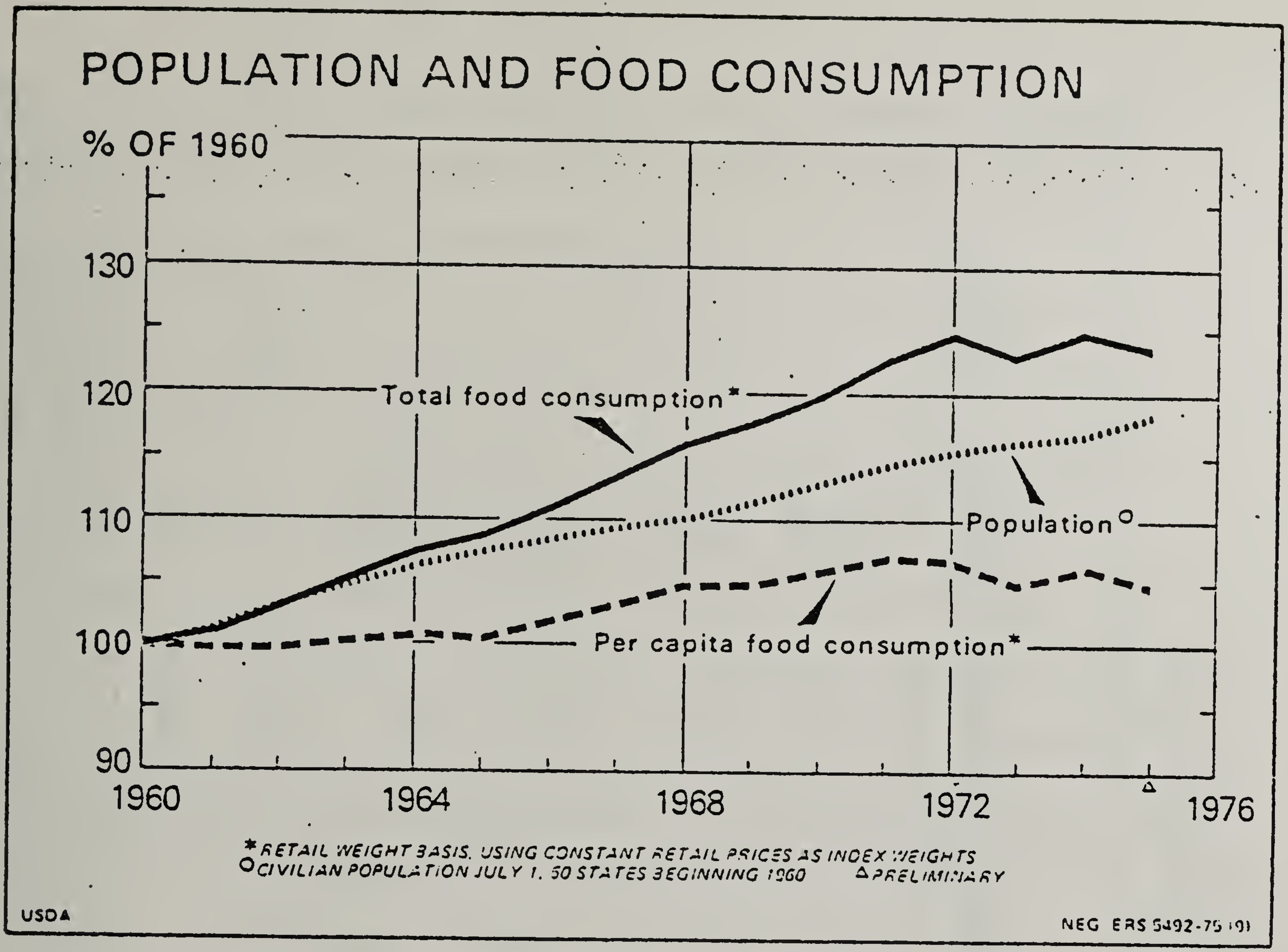
- Future demands for food and fiber for domestic consumption and export;
- The total land-water resource base - its use, productivity, and geographic location; and
- Trends in agricultural water withdrawals and consumption by region and by volume of supply.

Demands for Food and Fiber

Projected rates of demand are derived from expected increases in population, per capita disposal income, and exports. Future per capita demand estimates for food are based on historic trends of commodity consumption (Figure III-13). A projected population of 268 million by the year 2000 is used to estimate future domestic food demand.

Historic trends are used as the basis for estimating future levels of agricultural exports. A moderate level of agricultural exports assumed for the future partially takes into account the substantial increases that occurred in 1972 and 1973 (Table III-28). Important implications of agricultural exports, for example, are indicated by the fact that U. S. exports of food and fiber increased from $7.6 billion in 1971 to $21.5 billion in 1975. Exports will be highly dependent on world production and international trade conditions in the future.

Estimates of earnings and employment in food and fiber production are projected in terms of future conditions and adjusted for alternative policy assumptions such as variations in exports and domestic consumption patterns. Production of agriculture and forestry products involves identification and evaluation of several policy options for the management of the lands to produce these products.



Source: Agricultural Handbook No. 491, USDA, p. 36.

Figure III-13

POPULATION AND FOOD CONSUMPTION

Table III-28
PRODUCTION AND NET EXPORTS OF SELECTED FOOD AND FIBER COMMODITIES FOR THE UNITED STATES

Commodity	Unit	Average 1974-1976 Production	Average 1974-1976 Exports	Average 1974-1976 Imports	Estimated 2000 Production	Estimated 2000 Exports*	Estimated 2000 Imports
	(Million)						
Corn	Bushels	5559	1425		7110	1275 2067 3209	
Wheat	Bushels	2026	1054		1689	814 919 1479	
Soybeans	Bushels	1342	513		3453	684 1475 1700	
Cotton	Pounds	4864	1920		5168	1680 2020 2208	
Beef, Veal, and Pork	Pounds	34642		1809	55020		3275
Turkeys and Broilers	Pounds	10755	375		18520	333	

*Low and high figures are alternative estimates for low or high levels of export activity respectively. The center figure represents a moderate level of exports.

Land and Water Resources For Food and Fiber Production

The quantity and quality of land and water resources available determine the potential ability of U.S. water resource regions to meet estimated production levels for specific commodity groups.

The 21 regions include 2.3 billion acres of both land and water surface area. (Table III-29). Curently, there are 1.3 billion acres of land available for agriculture (including range and forest areas) in the United States. In 1975 cropland totaled 422 million acres of which 304 million acres were harvested. By 2000 total cropland is expected to be up slightly to 426 million acreas of which about 361 million acres will be harvested. Feed crops accounted for more than two-thirds of all crops grown in 1975. Increases in cropland harvested in 2000 will result largely from increases in feed crops (Table III-30). Other lands, not cropped today but with agricultural importance, include 108.2 million acres of privately owned forest and grazing woodland and 801.5 million acres of pasture, range, forest, and other land largely in public ownership.

Future agricultural production will be based primarily on the current supply of 422 million acres of cropland and about 885 million acres of pasture and range land. This land base will be reduced by the conversion of about 1.2 million acres annually to special uses such as urban and suburban areas, highways and roads, recreation and wildlife, public institutions, and public facilities.

Table III-29

SURFACE AREA AND LAND USE BY WATER RESOURCES REGIONS, 1975

Regions	Surface Area 1,000 Acres			Land Use 1,000 Acres					
	Total	Water	Land	Cropland	Pasture & Range	Forest & Woodland	Other Agri	Urban	Other
New England	44162	2458	41704	2769	957	32582	617	2705	2074
Mid Atlantic	66139	1977	64162	11688	4939	35466	2059	4418	5592
South Atlantic Gulf	173630	6807	166823	25259	15344	105334	4293	4747	11846
Great Lakes	85871	2526	83345	24907	3358	39152	4778	4333	6817
Ohio	102436	943	101493	32877	13995	43143	3011	3351	5116
Tennessee	27290	675	26615	4431	3532	14404	908	668	2672
Upper Mississippi	115631	2687	112944	64062	11644	24473	3643	2151	6971
Lower Mississippi	67292	2783	64509	20409	9928	27099	3828	895	2350
Souris-Red-Rainy	35021	1232	33789	20791	3376	6831	681	70	2040
Missouri	327133	3399	323734	105660	161774	29937	4006	1397	20960
Arkansas-White-Red	156163	1855	154308	44480	66559	33545	2244	1636	5844
Texas-Gulf	113726	2692	111034	25021	58632	20176	2160	2485	2560
Rio Grande	87764	542	87222	2869	63190	15048	611	396	5180
Upper Colorado	65848	558	65290	1951	35369	17881	415	47	9627
Lower Colorado	99103	456	98647	1485	52243	26749	2732	621	14817
Great Basin	89181	1760	87421	2623	61269	12251	267	378	10633
Pacific Northwest	173366	2329	171037	19159	51008	85041	1289	1055	13485
California	105497	1607	103890	10885	28021	43227	1218	3328	17211
Alaska	375304	12787	362517	21	238186	58635	29	68	65578
Hawaii	4126	31	4095	321	728	1774	67	21	1184
Caribbean	2283	10	2273	514	880	565	49	126	139
Total; Regions 1-18	1935253	37286	1897967	421326	645138	612339	38760	34681	145723
Total, Regions 1-21	2316966	50114	2266852	422182	884932	673313	38905	34896	212624

Table III-30
ESTIMATED LAND USE CROPPING PATTERNS, CROPLAND HARVESTED - 1975, 1985, 2000

(MILLIONS OF ACRES)

Crop	1975*	1985	2000
Barley and Oats	24.6	32.3	21.4
Corn and Sorghum	75.9	68.4	74.0
Cotton	12.1	8.1	6.6
Soybeans	48.2	49.0	82.5
Wheat	47.8	48.6	42.5
Roughage	72.6	93.5	106.4
Other	22.8	26.8	27.3
Total	304.0	346.7	360.7

*Projection based on average cropland harvested in 1971-1973.

The importance of water to agriculture is indicated by the 1975 irrigation of 45.3 million acres of farmland, most of which is part of the 422 million acres of total cropland (Table III-31). Irrigation is especially important in the production of high value crops such as vegetables, fruits, sugar, potatoes, cotton, and tobacco. In the future many lower valued crops such as corn and soybeans will be extensively irrigated in areas of water availability to reduce financial risks of crop failures. Figure III-14 shows the present extent of irrigated agriculture. The extent of changes in irrigation in the United States can be seen in Figure III-15.

Between 1975 and 2000 it is expected that about 56 million acres of irrigated land will be developed for agricultural use. More than 1 million acres of land for future crop production may be taken from currently wet soils and other land that requires minor improvements. Development of "new" land through drainage, irrigation, and clearing depends in the long run on the relative costs and returns from commodity production resulting from the introduction of these practices into the agricultural system.

The nine western conterminous regions contain about 65 percent of the Nation's agricultural land, about 51 percent of the cropland, and about 89 percent of the Nation's irrigated farmland. In these nine regions (Missouri, Arkansas-White-Red, Texas Gulf, Rio Grande, Upper and Lower Colorado, Great Basin, Pacific Northwest, and California) about 19 percent of the cropland is irrigated. Most of the growth in irrigation by 2000, about 10 percent over 1975, will occur in these western regions

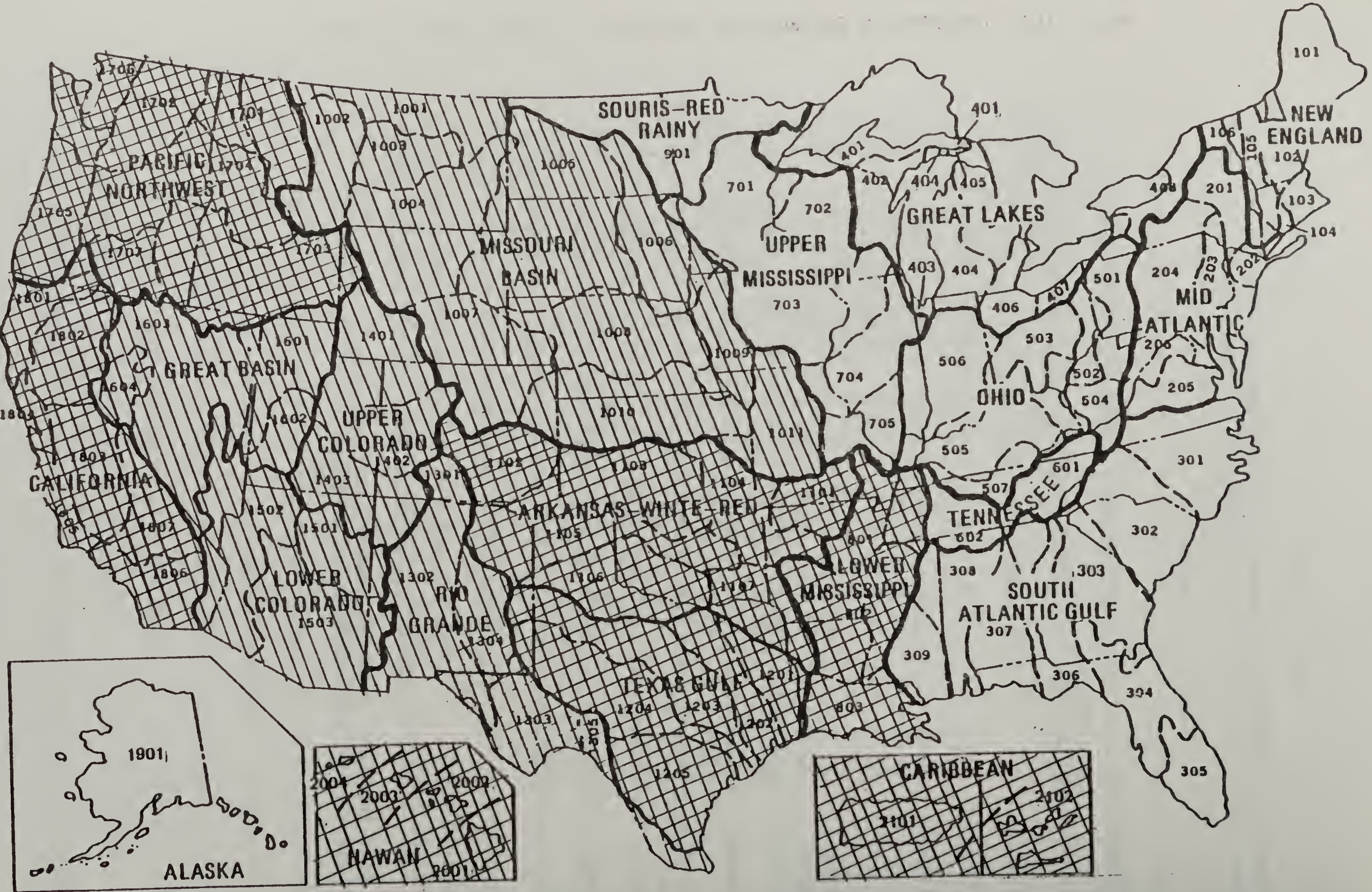
Table III-31

SUMMARY OF AGRICULTURAL LANDS, CROPLAND, AND IRRIGATED FARMLAND BY WATER RESOURCES REGIONS - 1975, 1985, 2000

(MILLIONS OF ACRES)

Region	Agricultural Land, Total*	Total Cropland			Irrigated Farmland		
	1975	1975	1985	2000	1975	1985	2000
New England	3.7	2.8	2.7	2.6	<0.1	<0.1	<0.1
Mid-Atlantic	16.6	11.7	11.6	11.2	0.3	0.4	0.5
South Atlantic-Gulf	40.6	25.3	25.7	27.5	2.0	2.6	3.0
Great Lakes	27.3	24.9	25.4	25.4	0.2	0.2	0.3
Ohio	46.9	32.9	33.0	33.0	0.1	0.1	0.1
Tennessee	8.0	4.4	4.4	4.4	<0.1	<0.1	<0.1
Upper Mississippi	75.7	64.1	64.3	64.7	0.2	0.3	0.4
Lower Mississippi	30.3	20.4	21.9	22.5	2.0	2.5	2.9
Souris-Red-Rainy	24.2	20.8	20.9	20.9	<0.1	0.1	0.3
Missouri	267.4	105.7	105.3	105.1	9.7	11.0	11.5
Arkansas-White-Red	111.0	44.5	44.6	45.1	4.8	5.4	5.5
Texas-Gulf	83.7	25.0	24.9	24.6	4.8	4.2	3.4
Rio Grande	66.1	2.9	2.8	2.8	2.0	1.9	1.9
Upper Colorado	37.3	2.0	2.1	2.1	1.4	1.5	1.6
Lower Colorado	53.7	1.5	1.4	1.4	1.3	1.2	1.1
Great Basins	117.6	2.6	2.8	2.8	1.7	1.5	1.6
Pacific Northwest	70.2	19.2	19.1	18.9	6.2	7.4	7.8
California	38.9	10.9	10.6	10.4	8.7	9.3	10.1
Alaska	238.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hawaii	1.0	0.3	0.3	0.3	0.1	0.1	0.2
Caribbean	1.4	0.5	0.5	0.4	0.1	0.1	0.1
Total, Regions 1-18	1066.5	421.3	423.6	425.3	45.3	49.6	52.2
Total, Regions 1-21	1307.1	422.2	424.4	426.1	45.5	49.8	52.4

*Agricultural land includes cropland, pasture, and range land. Other agricultural land, forest, and woodland are excluded.


SOURIS-RED RAINY
NEW ENGLAND
MID ATLANTIC
GREAT LAKES
UPPER MISSISSIPPI
OHIO
TENNESSEE
SOUTH ATLANTIC GULF
LOWER MISSISSIPPI
MISSOURI BASIN
ARKANSAS-WHITE-RED
TEXAS GULF
RIO GRANDE
UPPER COLORADO
LOWER COLORADO
GREAT BASIN
PACIFIC NORTHWEST
CALIFORNIA
ALASKA
HAWAII
CARIBBEAN
1901
2001
2002
2003
2004
2101
2102

☐ Less than one percent of land surface area is irrigated farmland

▧ One to three percent of land surface area is irrigated farmland

▦ Greater than three percent of surface area is irrigated farmland

Figure III-14. IRRIGATED FARMLAND BY WATER RESOURCES REGIONS, 1975

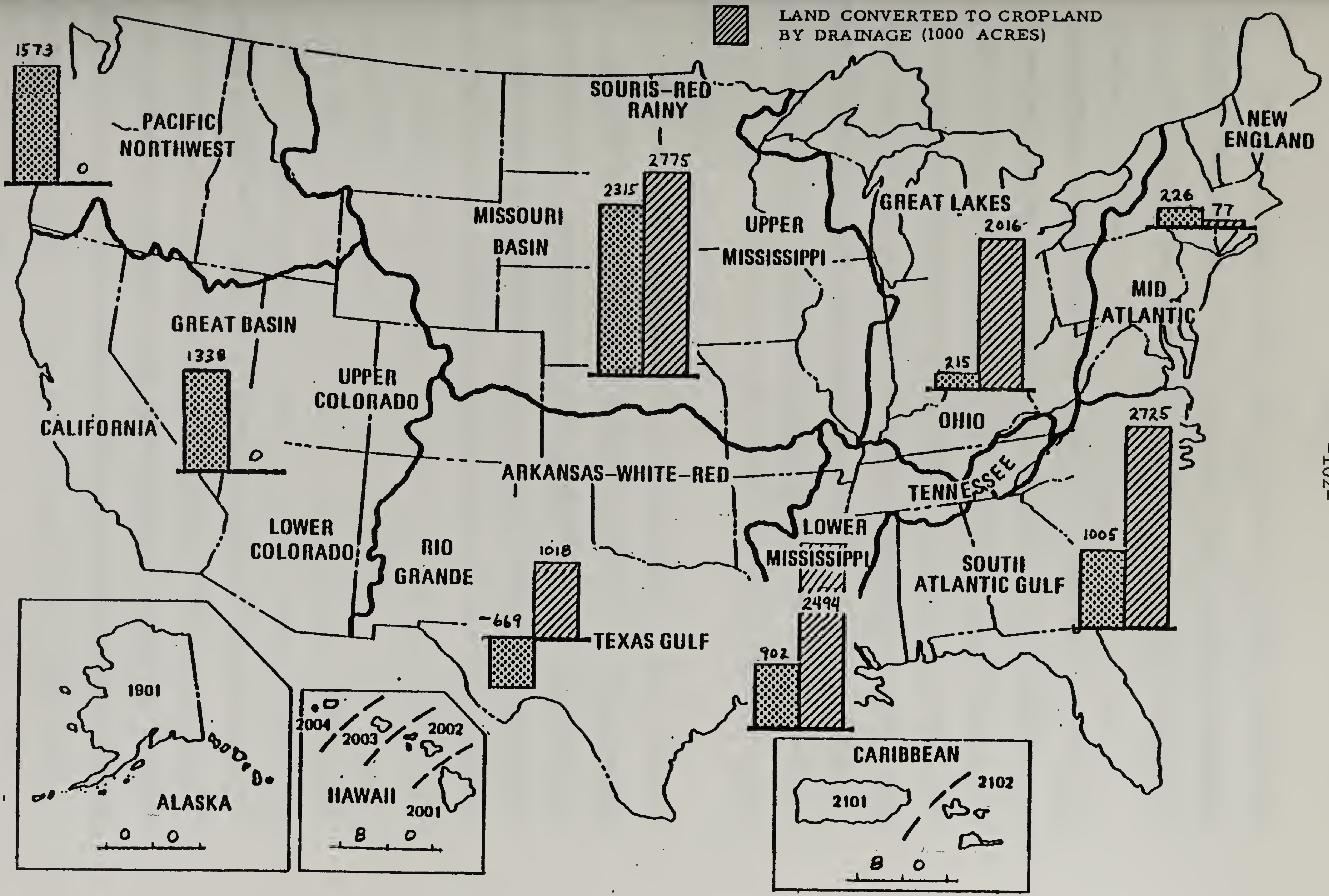

▨ LAND CONVERTED TO CROPLAND BY DRAINAGE (1000 ACRES)
1573
0
PACIFIC NORTHWEST
SOURIS-RED RAINY
2775
2315
MISSOURI BASIN
UPPER MISSISSIPPI
GREAT LAKES
2016
215
NEW ENGLAND
226
77
MID ATLANTIC
GREAT BASIN
1338
0
CALIFORNIA
UPPER COLORADO
OHIO
2725
1005
ARKANSAS-WHITE-RED
TENNESSEE
LOWER MISSISSIPPI
2494
902
SOUTH ATLANTIC GULF
LOWER COLORADO
RIO GRANDE
1018
-669
TEXAS GULF
1901
ALASKA
0
0
2004
2003
2002
2001
HAWAII
8
0
CARIBBEAN
2101
2102
8
0

Figure III-15

CHANGE IN IRRIGATED FARMLAND AND LAND CONVERTED TO CROPLAND BY DRAINAGE, 1975-2000.

where some 21 percent of cropland will be in irrigation by 2000. Substantial growth rates in irrigation can also be expected to develop in the South Atlantic-Gulf and Lower Mississippi Reigons by 2000.

Irrigation is also important in the eastern regions even though annual precipitation is more than twice the amount in many western regions. In the nine eastern water resource regions some 4.7 million acres of the 207 million acres of total cropland receive supplemental irrigation water. Most of the irrigated crops are relatively high in value, such as vegetables, fruits, tobacco, rice, and sugar beets. Additional water supplies could be developed to enhance crop production in these eastern areas, if commodity market demands continue to expand.

Potential means to expand agricultural output include: use of present and prospective production technology to increase crop yields; more intensive use of lands presently idle, fallow, grazed, or improperly managed; and development of land through irrigation, drainage, and clearing. These options may be heavily constrained by environmental factors.

Crop Yields

Changes in crop yields will continue to be a major determinant of land and water use for agricultural production. Trends in crop yields after World War II provided a partial basis for determining yields for the remainder of the century. As noted earlier, improvements in production technology such as improved cultivation practices, better seed varieties, improved fertilizer practices, and use of pesticides led to large yield increases. For example, in the 20 year period 1954-1974 (centered average 1952-56 and 1972-76) U. S. average yields of corn grain increased by 105 percent, rice and wheat yields increased by 65 percent, while soybeans and cotton yields increased by 32 and 35 percent. Additional yield increases are expected by 2000 of about 42, 45, 28, 57, and 65 percent, respectively, for the field crops listed above. Increased crop yields are expected to play a major role in achieving higher levels of production for future domestic and export needs.

Environmental Factors

The amount of water remaining in streams, the quantity of unused cropland, the extent of clearing and drainage of wetlands, and the degree of soil erosion are all important environmental factors. The environmental impact of water use by agriculture can be more critical for subregions within a major river basin than is indicated at a regional level. By the year 2000 it is estimated that nearly all water available for agriculture will be utilized in more than 30 western aggregated subregions. Diversion of larger quantities of water may reduce fishing opportunities on some streams. The quality of the remaining water in some streams may be affected due to higher salt concentrations. By the year 2000, it is estimated that under continuation of present policies 11 million acres of wet soils will have been drained and cleared for crop production, resulting in a reduction of recreational, scenic, and wildlife support attributes of the land.

The production of food and fiber introduces significant amounts of pollutants into the Nation's streams and reduces the quality of water resources. Water pollution from agriculture takes several forms: sedimentation, pesticides, fertilizers, animal wastes, and salinity. In each case, our knowledge is far from complete. However, enough is known about the geographical locations of the primary polluting activities to enable us to reach some tentative conclusions about the sources of the greatest pollution problems.

Cultivation of agricultural land increases the potential for movement of topsoil into streams by wind, rain, or irrigation water. The proportion of eroded soil which actually reaches streams depends on cultural practices and on the physical characteristics of the land. The best available estimates of the rate of soil loss reaching streams vary from 0 to 60 percent as these characteristics vary. The exact relationship between agricultural production and stream pollution is not known. But data on the relationship between cropland use practices and the amount of soil eroded from fields can be generalized (Table III-32). For the Nation as a whole soil erosion will drop from the 1975 rate of 8.6 tons per acre to 3.2 tons per acre in 2000. This reduction will result in not only higher land productivity but reduced sedimentation in lakes and waterways and improved scenic vistas because of fewer unsightly gullies and ditches. Reductions in soil losses will come about mainly from a greater use of conservation practices including contour farming, strip cropping, grassed waterways, and terracing.

Table III-32

PROJECTED QUANTITIES OF ANNUAL SOIL LOSS, 2000 AND APPLICATIONS OF PRETICIDES AND FERTILIZER, 1975 FOR PRODUCTION OF MAJOR CROPS BY WATER RESOURCES REGIONS

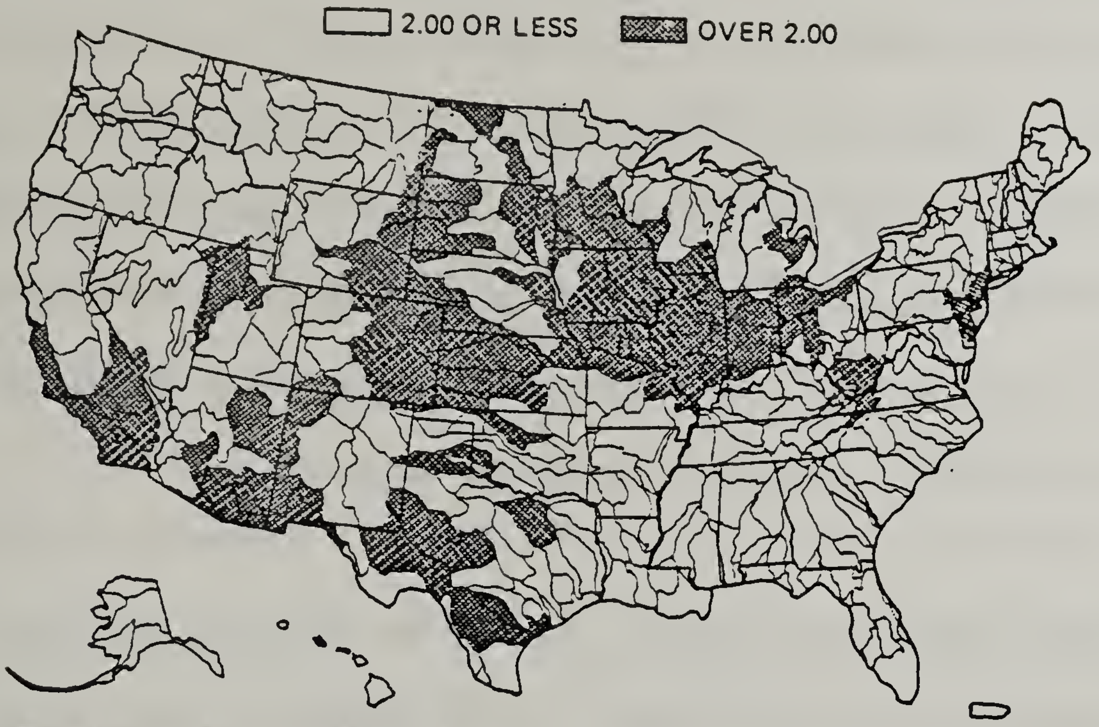
Region	Total Soil Loss 2000	Soil Loss Per Acre 2000	Pesticide Applications Per Acre 1975*	Commercial Fertilizer Applications Per Acre 1975*
	Million Tons	Tons	Pounds	Pounds
New England	0.4	1.0	2.4	129
Mid Atlantic	27.0	3.4	2.4	129
South Atlantic Gulf	105.4	5.8	10.9	234
Great Lakes	33.6	1.6	1.3	108
Ohio	93.6	3.4	1.4	138
Tennessee	9.8	3.9	12.8	160
Upper Mississippi	216.5	3.7	1.3	138
Lower Mississippi	89.6	5.7	3.8	93
Souris-Red-Rainy	19.6	1.1	0.5	50
Missouri	262.9	3.4	0.5	50
Arkansas-White-Red	72.2	2.0	3.1	74
Texas-Gulf	46.6	3.0	3.1	74
Rio Grande	4.0	2.7	0.9	57
Upper Colorado	2.6	2.5	0.9	57
Great Basin	2.7	1.7	0.9	57
Pacific Northwest	43.6	3.8	14.3	143
California	3.5	0.8	14.3	143
Total/Average	1,034.4	3.2	2.6	105

The principal determinant of agricultural chemical use is of course the particular crop cultivated. Practices currently employed by United States farmers to produce corn, for example, are nitrogen and herbicide intensive (Figure III-16). Corn production accounts for 45 percent of all herbicides used in United States agriculture. Current cotton production techniques are likewise insecticide intensive. About 47 percent of all the insecticides used in United States agriculture are applied to cotton.

Other important sources of agricultural pollutants are feed lot drainage wastes and return of irrigation waters to streams. Generally, the returned flows contain sediment, nutrient, chemical fertilizers, and pesticides. However, there are additional pollutants, especially from returned saline irrigation water throughout the arid West.

Irrigation expansion in the West is expected to be largely from ground water development by individual farmers. More knowledge of ground water supplies is needed so that irrigators may properly amortize investments. There is no adequate method to guage the publicly accepted rate of depleting water resources. Jurisdiction over ground water rests with State and local governments. Higher energy prices and prospectively lower crop prices will reduce the incentive to develop ground water for irrigation.

Several regions of the country are experiencing depletion of ground water reserves at rates faster than they are being replenished. The



Alaska, Hawaii, and Puerto Rico not drawn to scale

Annual mean values (total nitrogen as N) are in milligrams per liter (Source: CEQ analysis of data from the U.S. Geological Survey's National Stream Quality Accounting Network)

Figure III-16

TOTAL NITROGEN LEVELS IN STREAMS, 1975

most severely affected aquifers, are in the Texas-Gulf, Rio Grande, and Lower Colorado Regions. In addition, ground water depletion is emerging as a potential problem in the Ogalalla aquifer as far north as Wyoming. Irrigation is generally the principal use for this water. Ground water mining due to irrigation is also a problem in parts of the Great Basin and California Regions. Intrusion of salt water in the California coastal subregions and land subsidence in the Lower Colorado and California Regions accompany this ground water depletion.

In the West, most water rights are held by agricultural water users who can be expected, as in the past, to sell parts of their rights to municipal and industrial users. Projections assume that the supply of water available to agriculture will equal 1975 use levels plus 70 percent of the surface flow that remained in 1975 during the main irrigation season. In several areas, however (including the Texas High Plains, eastern New Mexico, and southern Arizona, water supplies are expected to diminish in line with historic trends and with increased water mining. Irrigation rates per acre are estimated as the net diversions required during years with relatively low seasonal rainfall. On this basis, water supplies would be more than adequate 8 years out of 10 for irrigation in the West.

In summary, agricultural production results in significant amounts of pollution of the Nation's waters. The challenge to public action in this regard is to devise policies which will effectively reduce pollution from agricultural sources without seriously impeding the production of low cost food and fiber or have seriously adverse income consequences to agricultural producers.

In addition to being required to adopt intensive practices of soil conservation, farmers may be restricted in the use of insecticides and herbicides in the future. Application of fertilizers may also be controlled, which will reduce economic losses for farmers. Technical knowledge is expected to keep pace with the needs to maintain a viable agricultural economy during the remainder of the century. The future is expected to reflect a continuation of present policies and programs that encourage farmers to include soil conservation practices as an integral part of their farm management decisions.

Agricultural Water Supply, Irrigation, and Other Uses

Increased water use in agriculture presents a dual problem of increasing competition from other uses and the probability that increased use will lower the quality of supplies.

For the nine western regions as a whole about 60 percent of the available water in 2000 will be used for agriculture. However, in several regions and aggregated subregions irrigation uses are anticipated to exert heavy pressure on supplies (Table III-33). Diminishing economic water supply is responsible for the expected decline in water use in the Texas-Gulf, the Rio Grande, and the Lower Colorado regions. In these three regions and in the Upper Colorado and Great Basin Regions it is expected that all economic supplies of water for agriculture will be essentially utilized by 2000. An aspect of the water situation not revealed by the regional data is the supply requirement relationship in aggregated subregions. In 2000 it is estimated that 32 of 52 subregions in the western regions will have water shortages in a dry year (Table III-34). Water supplies are expected to limit future irrigation in 11 additional aggregated subregions.

During the course of study for the Second Assessment it was determined that, if desired, greater efficiency in the use of a region's water supply could be achieved through intrabasin transfers. For example, in each aggregated subregion the water supply was computed to be the quantity used for irrigation in 1975 plus 0.7 of the unused surface outflow of the area during the primary irrigation months. Since the unused outflow was "retained" upstream, outflows of succeeding aggregated subregions were reduced accordingly in calculation of their supplies. Analysis was made of water transfer possibilities by simulation of the movement of "surplus" water to downstream aggregated subregions within a water

Table III-33

REGIONAL WATER AVAILABILITY AND USE FOR AGRICULTURE IN NINE WESTERN WATER RESOURCES REGIONS, 1975 AND 2000; AVERAGE YEAR

	1975			2000		
Region	Available (mgd)	Used (mgd)	Percent	Available (mgd)	Used (mgd)	Percent
Missouri	23,580	16,620	70	23,580	20,810	88
Arkansas-White-Red	11,930	8,430	71	11,340	8,480	76
Texas-Gulf	13,060	10,730	82	9,420	7,090	75
Rio Grande	4,330	4,350	100	4,170	4,040	97
Upper Colorado	3,060	2,450	80	3,060	3,060	100
Lower Colorado	4,550	4,190	92	3,910	3,890	100
Great Basin	3,720	3,720	100	3,720	3,720	100
Pacific Northwest	53,460	13,990	26	53,460	16,770	31
California	33,060	26,220	79	33,060	28,530	86
Total	150,750	90,700	60	145,520	96,390	66

Source: U.S. Department of Agriculture, "Food and Fiber Production and Related Resource Considerations", 1977, p.32.

Table III- 34

CURRENT AND PROJECTED REGIONAL IRRIGATED AVERAGE AND WATER SHORT AGGREGATED SUBREGIONS, 1975 AND 2000

Region	Irrigated acres		No. of subregions	No. of water-short subregions in 2000 a/
	1975	2000		
	--- Million acres ---			
Missouri	9,695	11,505	11	7
Arkansas-White-Red	4,765	5,545	7	4
Texas-Gulf	4,770	3,440	5	2
Rio Grande	1,984	1,865	5	4
Upper Colorado	1,365	1,627	3	3
Lower Colorado	1,283	1,127	3	2
Great Basin	1,739	1,621	7	4
Pacific Northwest	6,186	7,759	7	2
California	8,729	10,079	7	4
9 Western Regions	40,516	44,568	52	32
			-	-
Other Regions	5,002	7,639		
Total, Regions 1-18	45,302	52,207	-	-
Total, Regions 1-21	45,518	52,439		

a/ More than 90 percent of water available to agriculture is consumptively used.

resource region. A detailed analysis of the surplus transfers is presented in the Agriculture Appendix.

Water available for irrigation in the humid eastern water resource regions is generally adequate for the acreage irrigated in 1975 and is expected to remain adequate for the increased area of land to be irrigated in 2000. Temporary shortages may occur during periods of drought.

The quantity of water required in livestock production is included in the estimated regional uses in Table III-34. In 1975 livestock water use represents only 1 percent of agricultural water used in the western regions and about 9 percent in the eastern regions. Withdrawal and consumptive use is expected to increase 30 percent by 2000.

Water use for irrigation by region is shown in Table III-35. Livestock water use is shown in Table III-36 and total agricultural water use is summarized in Table III-37.

Table III- 35

SUMMARY OF WATER WITHDRAWALS AND CONSUMPTION FOR IRRIGATION BY WATER RESOURCES REGIONS-1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	35	41	46	25	29	33
Mid-Atlantic	265	366	481	196	269	354
South Atlantic-Gulf	3,464	4008	4509	2752	3184	3597
Great Lakes	145	211	282	114	169	232
Ohio	47	68	91	37	53	74
Tennessee	14	18	21	11	14	17
Upper Mississippi	192	283	387	153	230	323
Lower Mississippi	4580	4,559	4,444	3,065	3,204	3,272
Souris-Red-Rainy	46	144	434	37	116	350
Missouri	31,636	39,376	36,236	14,214	17,597	17,607
Arkansas-White-Red	9,980	10,483	9,776	7,048	7,468	7,125
Texas-Gulf	11,538	9,333	7,427	9,347	7,597	6,100
Rio Grande	5,684	5,498	4,873	3,886	3,920	3,570
Upper Colorado	6,400	7,223	6,672	2,194	2,657	2,741
Lower Colorado	7,989	7,299	6,343	4,026	3,962	3,720
Great Basins	6,969	6,120	5,825	3,225	3,082	3,196
Pacific Northwest	33,181	34,639	29,961	11,026	13,362	13,213
California	34,611	34,863	34,764	24,282	25,134	26,311
Alaska	4	4	4	3	3	3
Hawaii	1,447	1,226	951	474	481	473
Caribbean	516	490	319	276	289	195
Total, Regions 1-18	156,776	164,532	152,572	85,638	92,047	91,835
Total, Regions 1-21	158,743	166,252	153,846	86,391	92,820	92,506

Table III-36
SUMMARY OF WATER WITHDRAWALS AND CONSUMPTION FOR LIVESTOCK BY WATER RESOURCE REGIONS - 1975, 1985, 2000; AVERAGE YEAR (MILLION GALLONS PER DAY)*

	Withdrawals and Consumption		
Region	1975	1985	2000
New England	18	19	19
Mid-Atlantic	68	69	71
South Atlantic-Gulf	134	166	202
Great Lakes	85	85	87
Ohio	113	127	139
Tennessee	27	32	37
Upper Mississippi	230	283	304
Lower Mississippi	44	54	63
Souris-Red-Rainy	26	33	37
Missouri	450	559	658
Arkansas-White-Red	215	238	279
Texas-Gulf	180	197	228
Rio Grande	38	39	44
Upper Colorado	27	31	34
Lower Colorado	47	52	60
Great Basins	33	34	36
Pacific Northwest	72	86	102
California	98	118	136
Alaska	1	1	1
Hawaii	2	3	3
Caribbean	5	8	11
Total, Regions 1-18	1,905	2,222	2,536
Total, Regions 1-21	1,912	2,233	2,551

*All water withdrawn is consumed.

Table III-37

ESTIMATES OF WATER WITHDRAWALS AND CONSUMPTION FOR IRRIGATION AND LIVESTOCK WATER USE - 1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Agricultural Water Use	Withdrawal 1975	Withdrawal 1985	Withdrawal 2000	Consumption 1975	Consumption 1985	Consumption 2000
Irrigation, Regions 1-18	156,776	164,532	152,572	85,638	92,820	91,835
Regions 1-21	158,743	166,252	153,846	86,391	92,820	92,506
Livestock, Regions 1-18	1,905	2,222	2,536	1,905	2,222	2,536
Regions 1-21	1,912	2,233	2,551	1,912	2,233	2,551
Total, Regions 1-18	158,681	166,754	155,108	87,543	94,269	94,371
Total, Regions 1-21	160,655	168,485	156,397	88,303	95,053	95,057

The region having the highest water withdrawals and consumption is California which accounts for about 22 percent of the total water use. Irrigation means much to California and the Nation in terms of fresh vegetables and valuable tree crops. The Pacific Northwest Region is second in water withdrawals but third in terms of consumption. The Missouri Region is third in withdrawals and second in consumption.

The agricultural sector of the economy competes with other sectors for available water in many areas, particularly in the West. Increased costs for water supply is responsible for the expected decline in irrigation water withdrawn in the Texas-Gulf, Rio Grande, and Great Basin Regions by 2000. Expanded irrigation largely by private means and from ground water sources will occur in the other regions.

The growth of irrigation in the West depends upon improved efficiency in water use and the continued development of ground water supplies. Despite extreme drought and water shortages in 1976 and 1977, California's agriculture has managed to nearly maintain output due to advanced irrigation technology. Computerized irrigation scheduling services enable the optimum application of irrigation water and fertilizer. California also leads in the reclamation of municipal waste water for irrigation.

Irrigation efficiency (the ratio of water added to the plant root zone relative to the total diverted from the source or applied to the field) can be increased by improved irrigation methods. Drip irrigation is a relatively expensive application method adapted to the irrigation of perennial crops (e.g., orchards) and vegetables. In addition to being 90 percent efficient, it significantly increases yields. Reuse systems added to gravity irrigation methods will improve the low water use efficiencies of gravity methods. Farmers are learning to improve irrigation timing by soil moisture testing with gypsum blocks and tensionmeters.

Irrigation from ground water ultimately affects stream flows or in closed basins depletes ground water supplies accumulated over centuries. The 1973 National Water Commission report recognized the lack of Federal jurisdiction in ground water management. National concern, according to the Commission, is that depletion be planned--that States regulate ground water withdrawals to take account of present and future value of the resource and the interrelationship with surface sources. The regulation should be in coordination with Federal resource programs.

Comparison of National and State-Regional Futures

With irrigated agriculture currently accounting for over 80 percent of all fresh water consumed from ground and surface sources, it is important to discuss the impacts that alternative courses of future agricultural programs and policies might have on the Nation's water resources. Therefore, alternative futures are considered and evaluated. The net results of these evaluations show that the United States is not running out of farmland, that agricultural productivity is not being compromised, and that anticipated domestic food and fiber needs plus moderately high export demands can be met without severely stressing the carrying capacity of the Nation's water and land resources (under the assumption that reasonable land and water management practices will be implemented). Well-considered policies concerning farmland use and conservation are, nevertheless, vital. Potentially important constraints on production include: higher energy costs, water availability, unfavorable weather, increased costs of nonland inputs, environmental restrictions, a declining rate of advancement in agricultural technology, continued conversion of productive farmland to nonagricultural uses, and volatile export demands. Both the State/Regional and National Futures show that about 422 million acres are currently in cropland, and by year 2000 an additional 4 to 6 million acres of cropland will be required. However, only about 303 millions acres are currently harvested annually and by year 2000, the acres harvested must increase by about 55 million acres (18 percent) in order to produce about 39 percent more food and fiber products.*

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*Feed grains, food grains, oil seeds, fruits, vegetables, potatoes, and livestock meats.

Some of this additional cropland will come from the draining and clearing of about 5.6 million acres of forest land and the draining of a little over 5.5 million acres of pasture land. On the other hand, considerable acreages are projected to be taken out of crop production due to the factors shown in Table III-38.

While both futures show essentially equal increases in total cropland harvested there are considerable differences in the current and future irrigated farmland (Table III-39). The sum of the State/Regional Futures show an increase of about 18 million irrigated acres (33 percent) are needed whereas the National Future shows an increase of only 7 million irrigated acres (15 percent). Both Futures assume that there would be little Federal financing of new irrigation projects and that the major additions would be due primarily to private projects.

As displayed in Figure III-38, the largest regional differences between the National and State/Regional futures are concentrated in the central portion of the Nation. The reasons for those differences vary by region. In the Texas-Gulf Region the primary reason for the difference is that the National Future assumed that by year 2000 ground water depletion would have a significant impact on reducing the amount of irrigation whereas the State of Texas indicates that the effect of depletion will not cause a decline in irrigated acreage until after 2010 or 2020.

Table III-38
FACTORS CONTRIBUTING TO CHANGES IN FARMLAND ACREAGES BETWEEN 1975 AND 2000 IN THE NATIONAL FUTURE

QUANTIFIED FACTORS CONTRIBUTING TO DECREASED CROPLAND

1. URBAN LAND EXPANSION	.400 ACRES PER CAPITA FOR ALL TIME PERIODS
2. PRIMARY HIGHWAYS	40 ACRES/MILE ON NEW HIGHWAYS 20 ACRES/MILE ON EXPANSIONS
3. SECONDARY HIGHWAYS	16,000 ACRES/YEAR (1969-1980)
4. MAJOR AIRPORTS	5,000 ACRES EACH
5. FEEDER AIRPORTS	160 ACRES EACH
6. STATE RECREATIONAL LAND	100,000 ACRES/YEAR (1969-1980) 75,000 ACRES/YEAR (1980-2000)
7. LOCAL AND PRIVATE RECREATIONAL LAND	BASED UPON PER CAPITA POPULATION INCREASE PROJECTIONS .010 to .020 ACRES (1969-1980) .035 ACRES (1980-2020)
8. FEDERAL RECREATIONAL LAND	ESTIMATED BY FEDERAL AGENCIES
9. SURFACE MINING -- COAL, SAND, GRAVEL AND OTHER	150,000 ACRES BY 1980 310,000 ACRES BY 2000 480,000 ACRES BY 2020 (no account taken for oil shale developments)

Quantified Factors Contributing to Increased Cropland

1. Clearing and Draining	5.6 Million acres by 2000
2. Clearing Pastureland	5.5 Million acres by 2000

Table III-39

IRRIGATED FARMLAND BY WATER RESOURCES REGIONS -- COMPARISON OF PROJECTED INCREASES BETWEEN 1975 AND 2000 FOR NATIONAL AND STATE-REGIONAL FUTURES

Region	National Future 1975 (Millions Acres)	Increase in Irrigated Farmland 1975 to 2000			
		National Future (NF)		State-Regional Future (SRF)	
		Absolute Increase (Millions Acres)	Increase (Percent)	Absolute Increase (Millions Acres)	Increase (Percent)
New England	0.04	0.01	33	0.01	33
Mid-Atlantic	0.26	0.21	80	0.27	90
South Atlantic Gulf	2.04	1.00	49	1.27	54
Great Lakes	0.16	0.17	104	0.17	104
Ohio	0.06	0.05	79	0.05	79
Tennessee	0.02	0.008	53	0.0008	53
Upper Mississippi	0.20	0.23	112	0.23	112
Lower Mississippi	1.97	0.89	45	0.34	14
Souris-Red-Rainy	0.04	0.28	764	0.28	764
Missouri	9.70	1.81	19	5.94	52
Arkansas-White-Red	4.77	0.78	16	3.37	59
Texas-Gulf	4.77	-1.33	-28	+1.15	+22
Rio Grande	1.98	-0.12	- 6	+0.17	+ 7
Upper Colorado	1.37	0.26	19	0.33	22
Lower Colorado	1.28	-0.16	-12	+0.16	+12
Great Basins	1.74	-0.12	- 7	+0.01	1
Pacific Northwest	6.19	1.57	25	2.23	30
California	8.73	1.35	15	1.39	15
Alaska	0.004	0	0	0.04	1000
Hawaii	0.14	0.008	6	0.008	6
Caribbean	0.07	0.008	11	0.008	11
Total, Regions 1-18	45.3	6.91	15	17.4	33
Total, Regions 1-21	45.5	6.92	15	17.4	33

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* A plus indicates that the SRF is significantly higher than the NF; a minus sign indicates the opposite Regions in which the change in irrigated farmland differs by at least 30 percentage points.

In the Arkansas-White-Red Region a similar condition exists; however, the magnitude of the acres going out of irrigated production is overshadowed by additional irrigated acreages. In the Missouri Region the primary reason for the difference lies it fact that the SRF estimates that recent trends of installing centerpivot irrigation systems without Federal assistance will continue into the future at a rate considerably higher than projected in the National Future.

Summary

Growth in world population and increases in per capita income will cause a substantial rise in the demand for U.S. food and fiber products over the next 25 years. This will require greater productivity of the Nation's land resources. At the same time concern about environmental quality draws attention to the use of the Nation's water and land resources by agriculture. The forces--increased demand for output and concern with environmental quality--will lead to more frequent tradeoffs in the future between food and fiber and environmental goals.

Food and fiber production currently accounts for one half of all water withdrawn and 80 percent of the water consumed from surface and ground water sources in the United States. Agriculture is projected to maintain its predominant role in the use of U.S. water resources. In particular, irrigated agriculture is projected to expand from its present base of 45.5 million acres to 52.4 million acres by the end of this century.

This in turn will increase consumptive use of water from 86 bgd to 93 bgd.

In many regions of the United States available water is fully appropriated. Water limits the expansion of agriculture in these areas. Under "dry-year" assumptions agriculture's water supply will be completely utilized in much of the western United States by 2000. Agriculture in large parts of the Missouri, Arkansas-White-Red, Texas-Gulf, Rio Grande, Upper and Lower Colorado, Great Basin, and California Regions currently uses over 90 percent of the available water, or will do so by 2000. Any above-trend in water requirements for other uses--navigation, wildlife maintenance and recreation, or energy development--would necessarily imply reduced agricultural production in many of these areas.

Mining of ground water in large portions of the Great Plains is expected to substantially reduce the availability of water for agriculture by 2000. Adjustment to the depletion will be a major policy issue in the water resources field.

Agricultural pollutants entering streams present a significant water quality problem in both the humid East and the more arid West. Eroded topsoil, leaching of pesticides and fertilizers, drainage from feed lots, and irrigation-induced stream salinity are the principle forms of agricultural water pollution. Application of more stringent restrictions to reduce agricultural pollutants could reduce the cropland reserve even further.

At present U.S. agriculture has a cropland reserve of about 40 to 50 million acres. This reserve flutuates from year to year depending on world food demand, climatic conditions, and stored grain reserves. The development of wetland areas into productive cropland is projected to have a small but significant effect (an increase of about 23 percent) on the supply capability of the food and fiber sector between now and 2000. Improved production technology and growth in commodity demand between now and 2000 are expected to keep pace with each other to maintain a substantial cropland reserve.

The best use of the Nation's water and related land resources depends on the value of these resources in meeting objectives for food and fiber production, environmental quality, and local needs. Determining how to achieve this best use will require careful analyses of alternative resources and management options, the consequences of these options for local communities and the national economy, and public debate about the relative importance of competing objectives. This information will be necessary to guide public and private action in developing and using the Nation's water resources.

For the nine western regions as a whole only about 60 percent of the available water in 2000 will be used. However, in several regions and aggregated subregions irrigation uses are anticipated to exert heavy pressure on supplies (Table III-33). Diminishing economic water supply is responsible for the expected decline in water use in the Texas-Gulf, the Rio Grande, and the Great Basin Regions. In these three regions and the Upper and Lower Colorado Regions it is expected that all economic supplies of water for agriculture will be essentially utilized by 2000. An aspect of the water situation not revealed by the regional data is the supply requirement relation in aggregated subregions. In 2000 it is estimated that 32 of 52 aggregated subregions in the western regions will have water shortages in a dry year (Table III-34). Water supplies are expected to limit future irrigation in 11 additional aggregated subregions.

During the course of study for the Second Assessment it was determined that, if desired, greater efficiency in the use of a region's water supply could be achieved through intrabasin transfers. For example, in each aggregated subregion the water supply was computed to be the quantity used for irrigation in 1975 plus 0.7 of the unused surface outflow of the area during the primary irrigation months. Since the unused outflow was "retained" upstream, outflows of succeeding subregions were reduced accordingly in calculation of their supplies. Analysis was made of water transfer possibilities by simulation of the movement of "surplus" water to downstream aggregated subregions within a water resource region. A detailed analysis of the surplus transfers is presented in the agriculture appendix.

PART III

CHAPTER 6

WATER REQUIREMENTS FOR ENERGY PRODUCTION AND RELATED USES

Water is essential to energy development and production -- to extract raw materials from the earth, to process raw materials into usable fuels, to convert fuels to more useful forms of energy, and to dispose of wastes from energy production. Water is also used directly for hydroelectric generation, for transportation of basic resources and fuels, and for dissipation of waste heat (cooling) from steam-electric generating plants as well as steam to drive the generators.

The largest user of water for energy purposes is the electric utility industry and is tabulated separately from other industrial uses because of its magnitude. In 1975 water withdrawals for steam-electric power accounted for 94 percent of all withdrawals for energy production and 26 percent of total U.S. freshwater withdrawals. Although the production of electricity from steam requires large water withdrawals it accounted for only 1 percent of total freshwater consumption in 1975. The consumption of water is only 2 percent of the freshwater withdrawn for steam-electric power generation.

By 1985 coal and nuclear fuels are expected to provide two-thirds of the total energy to generate electricity. The use of coal to generate electricity is projected to double and the use of nuclear plants now under construction is expected to quadruple nuclear power by that time. However, the few new plans for nuclear plants during the past two years indicate a distinct possibility of reduction in nuclear power growth in the late 1980s.

The energy crises, the economy, increasing environmental concerns, changing regulatory requirements, industry financial difficulties, and rising costs of electricity have all cast doubt on the magnitude of future demand for electric power and the method to supply that demand. Several projections of electric energy have been made to reflect various opinions on future electricity requirements and on acceptable generating facilities needed to meet the requirements. All projections show that the demand for electricity will increase in the future with the different assumptions largely affecting the time frame during which certain load levels will be reached. Water use projections for energy production presented in the Second Assessment reflect anticipated broad National policy commitments to energy conservation efforts, technological advances in new types of generating facilities such as solar and geothermal, and National environmental goals.

Water supply for energy resources development will be of concern only in a few areas in the United States. Energy production, however, will continue to receive strong National attention and the expected development of more domestic sources of energy will produce problems especially in the areas of heat discharge to the environment and in the management of water resources to produce energy with the least conflict with competing needs for water.

Water Requirements for Energy Production

Water withdrawal and consumption for energy generation vary with the type of fuel being extracted, processed, and used. For example, estimates made during Project Independence indicate that mining of coal requires less than one gallon of water per million British thermal units (Btu) whereas the extraction of oil and gas requires about 3 gallons of water per million Btu (Table III-40). For processing oil, refineries need about 7.6 gallons of water per million Btu; gas processing plants use about 1.7 gallons of water per million Btu, and nuclear fuel mining and processing requires about 14 gallons of water per million Btu. These typical rates of 120 gallons per million Btu for power generation with fossil fuels and 234 gallons per million Btu for nuclear fuel plants are useful comparisons of alternatives available for producing energy through the use various fuels and processes. The data on withdrawals and consumption projected for this Assessment may vary from the typical 1974 estimates for different assumptions on heat rates and technical improvements in cooling efficiency.

TABLE III-40
TYPICAL WATER REQUIREMENTS FOR ENERGY PRODUCTION BY TYPE OF FUEL AND PROCESS

Type of Fuel of Process	Standard Unit	Water Requirements		Major Water Use
		Standard Unit (gallons)	Million BTU (gallons)	
1. COAL				
Western Coal Mining	ton	6.0-14.7	0.25-0.61	Dust control and washing
Eastern Coal Mining	ton	15.8-18.0	0.66-0.75	Dust control and washing
Coal Gasification	MSCF*	72.0-158	72-158	Process and cooling
Coal Liquification	barrel	1134-1750	31-200	Process and cooling
2. PETROLEUM				
Oil and Gas Production	barrel	1.7-3.0	3.05	Well drilling and recovery
Oil Refining	barrel	43.0	7.58	Process and cooling
Oil Shale Production	barrel	145.4	30.1	Mining, cooling processing and waste disposal
Gas Processing	MSCF*	1.67	1.67	Cooling
3. NUCLEAR FUELS	-	-	14.3	Mining and processing
4. POWER GENERATION				
Fossil Fuels	kwh	0.41	120.16	Cooling
Nuclear Fuels	kwh	0.80	234.46	Cooling
Geothermal	-	-	527	Cooling and extraction

*Million Standard Cubic Feet

Source: United States Federal Energy Administration. "Project Independence", Project Independence Report, p. 304, United States Government Printing Office, Washington, D.C. 20402

The principal use of water for electrical energy production is in steam-electric generating plants for condenser cooling purposes. The principal types of cooling systems now in use or proposed for steam-electric plants are: once-through using fresh or saline water, cooling ponds including spray ponds, wet cooling towers, and dry cooling towers. In some cases a combination of systems may be used and water withdrawal and consumption requirements vary widely among these systems (Table III-41).

Total Energy Consumption and Production

The projected energy consumption for the United States serves as the basis for estimates of water requirements for the years 1975, 1985, and 2000 (Table III-42). The production of energy and the extraction of fuels from which energy is produced accounted for nearly 27 percent of total U.S. freshwater withdrawals but less than 2 percent of total freshwater consumption in 1975. By 2000 freshwater withdrawals for steam-electric energy production will remain about the same for total withdrawals, but consumptive use will increase to nearly 8 percent of total consumption. Consumptive use will increase from less than 2 percent of 1975 withdrawals to more than 13 percent of withdrawals by 2000 as recycling and heavier cooling uses develop. The amount of water required depends on both the absolute level of energy usage and the means by which that energy is produced.

Table III-41
AVERAGE WITHDRAWAL AND CONSUMPTIVE WATER USE FACTORS OF STEAM-ELECTRIC PLANT PROCESSES

Plants	Once Through		Cooling Ponds		Cooling Towers	
	Fossil[1]	Nuclear	Fossil[1]	Nuclear	Fossil[1]	Nuclear
Installed before 1975						
Heat output rate, Btu per kWh	9,800	10,500	9,800	10,500	9,800	10,500
Water withdrawal, gal. per kWh[2]	0.45	0.60	0.54	0.72	0.83	1.11
Water consumption, gal. per kWh	0.28	0.37	0.36	0.48	0.56	0.74
Installed by 1985						
Heat output rate, Btu per kWh	9,700	10,300	9,700	10,300	9,700	10,300
Water withdrawal, gal. per kWh[2]	0.45	0.59	0.53	0.71	0.82	1.08
Water consumption, gal. per kWh	0.27	0.36	0.36	0.47	0.55	0.72
Installed by 2000						
Heat output rate, Btu per kWh	9,600	10,000	9,600	10,000	9,600	10,000
Water withdrawal, gal. per kWh[2]	0.44	0.56	0.53	0.68	0.81	1.03
Water consumption, gal. per kWh	0.27	0.34	0.35	0.45	0.54	0.69

[1] Reflects base load operation (greater than 40 percent plant factor).

[2] Withdrawal for once-through cooling based on condenser temperature rise of 13 F.

Note: Consumption factors reflect assumption that 50, 65, and 100 percent of waste heat from the condenser will be dissipated through evaporative processes for once-through, cooling ponds, and cooling towers, respectively.

Table III-42
TOTAL UNITED STATES ENERGY CONSUMPTION BY FUEL SOURCES

Fuel Source	Historical*			Projected**		
	1950	1960	1970	1975	1985	2000
	(Quadrillion BTUs (QUADS))					
Coal	12.9	10.1	12.9	13.1	21.3	34.8
Petroleum a/	13.5	20.1	29.6	32.7	45.6	51.2
Natural Gas a/	6.2	12.7	22.0	20.4	20.1	19.6
Nuclear	-	0.1	0.2	1.8	11.8	46.1
Hydroelectric	1.4	1.7	2.7	3.3	3.5	4.3
Synthetic Fuels	-	-	-	-	0.6	2.5
Geothermal	-	-	-	-	0.2	1.8
Solar	-	-	-	-	-	0.3
Wind and Other	-	-	-	0.3	0.2	1.9
TOTAL	34.0	44.6	67.4	71.6	103.1	162.5

a/ Includes imports

Sources:

*United States Federal Energy Administration, "Project Independence", Project Independence Report, pp. 9-16, Appendix A1, United States Government Printing Office, Washington, D.C. (November 1974)

**Estimated for the Second National Water Assessment by the Federal Power Commission, Bureau of Mines, Federal Energy Administration, and Energy Research and Development Administration.

The quantities of energy consumed from each of the various power sources from 1850 to 1975 and the projected consumption levels to 2000 are shown in Figure III-17. These data illustrate the changing relationships among sources such as wood, petroleum, coal, nuclear, and other. Unfortunately these data have limited horizons concerning the development of new sources such as shale oil, cellulose, and the atom. Energy produced from petroleum will decrease from 46 percent in 1975 to 32 percent of the total in 2000 (Figure III-18). However, the actual Btus of energy produced from petroleum will increase (Table III-42). Energy production from natural gas will begin to decrease after 1970 and the relative importance of gas as an energy source will decline from 29 percent in 1975 to only 12 percent in 2000. In this 1975-2000 period the output of hydroelectric power from run-of-river and pumped-storage plants will increase by one third, but the relative share will decline from 3.3 to 2.6 percent. Consumption of coal for energy production is projected to increase by over 165 percent, but coal's share of total production will remain fairly constant at about one fifth of the total. Nuclear power energy production is projected to dramatically increase by about 25 times the 1975 level by the year 2000 with its share increasing from 2 percent to 28 percent of the total energy sources.

Electric Power Generation

The two principal methods of electric power generation in the United States are the conversion of heat energy to electricity by

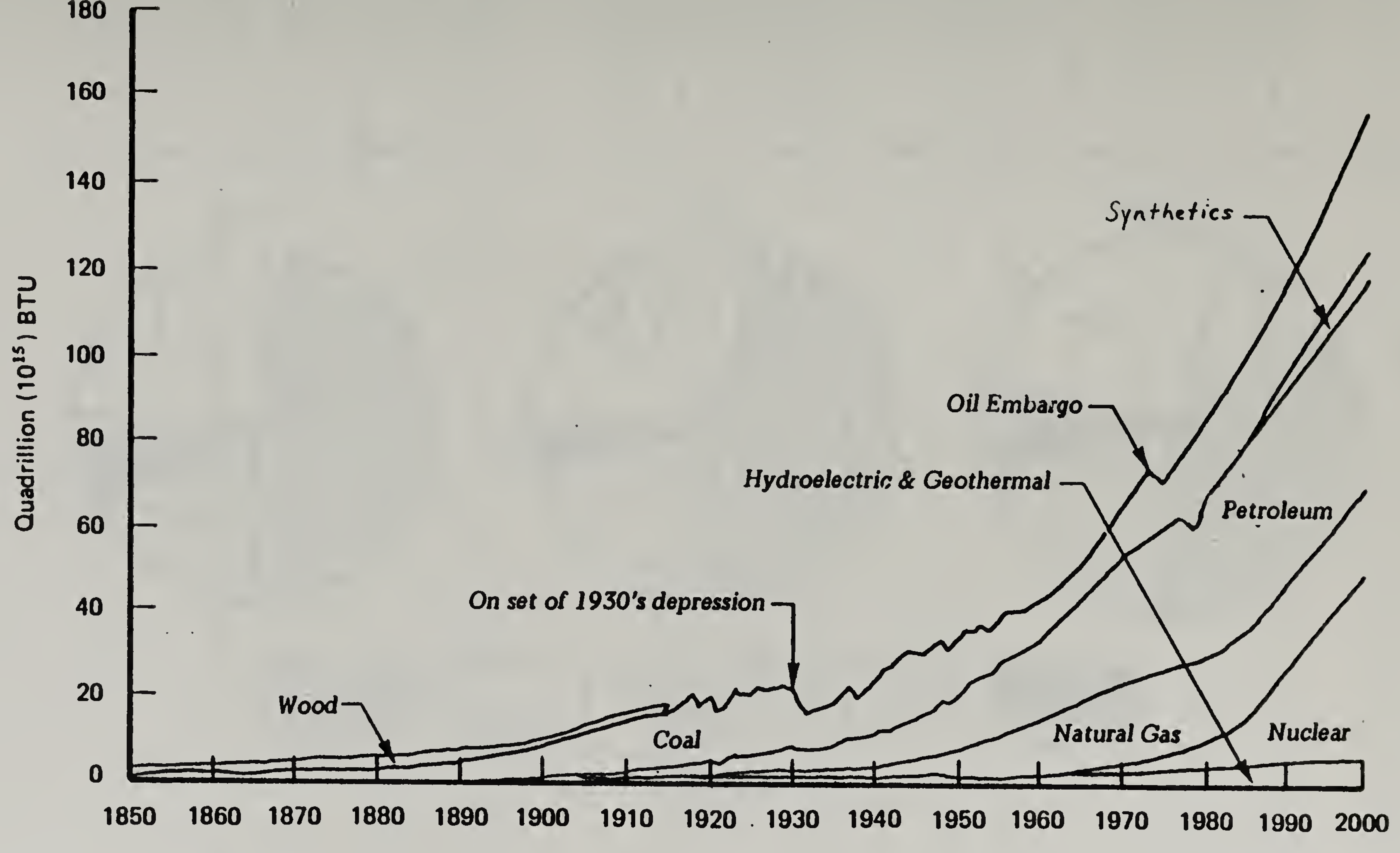
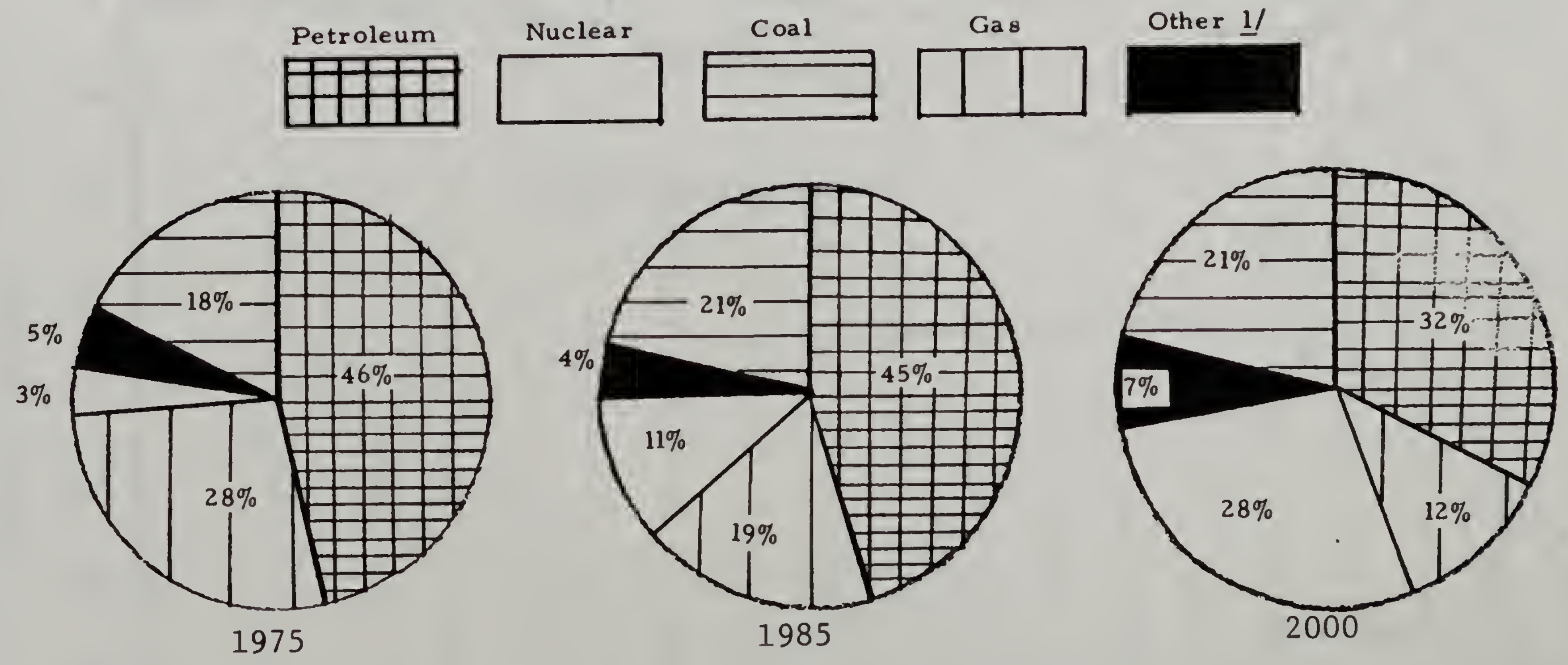


Figure III-17

UNITED STATES ENERGY CONSUMPTION BY SOURCE OF FUEL, 1850-2000

Figure III-18

CURRENT AND PROJECTED TOTAL ENERGY CONSUMPTION BY SOURCE OF FUEL -1975, 1985, 2000



1/ Other includes hydroelectric, synthetic fuels, geothermal, solar, wind, and other.

steam-electric plants (about 85 percent of the total national generation) and the conversion of kinetic energy in falling water by hydroelectric plants (about 15 percent of the total national generation).

Projections of electric power requirements for the Nationwide Analysis for the Second Assessment were made for each of the 50 Federal Power Commission (FPC) power supply areas (PSAs). These areas, comprising the total United States and the Caribbean territories, were established to facilitate electric power studies. The PSA projections were grouped into 19 power market areas -- 16 within the conterminous United States and one each for Alaska, Hawaii, and Caribbean regions. Where possible these market areas were selected to coincide with the boundaries of formal power pools, planning organizations, or other electric utility groups organized for the purpose of intra-group energy transfers and enhanced reliability of operation.

The generating capacity to supply these power requirements consisted of existing generating units and new units scheduled for operation in 1975. Units scheduled to be retired by 1975 were deleted. Generation by individual units was based on historical operation modified to reflect load changes and the type of new generation scheduled to be added.

The historical trends of the PSA load segments, both energy and demand, obtained from regression and correlation analysis were extrapolated to 1985 and 2000 with adjustments to conform with the Series E OBERS population and economic projections. These energy requirements were then aggregated on a regional basis, compared with regional and national forecasts, and checked for reasonableness by determining the resulting per capita use.

This methodology was used to develop the National Future projections during 1973. Due to significant changes in electric energy use trends in 1974 and 1975 these projections were compared to the latest actual generation data through May 1975; to the Regional Reliability Council's projections dated April 1, 1975; to the President's 1975 Scenario (FEA); and to the 1975 ERDA staff projections.* These projections were modified to reflect changes in energy use resulting from the oil embargo, the 1974-75 recession, and the 1974-75 national concern for efficiency in energy consumption. The National Future projections were developed separately for each of the target years of 1975, 1985, and 2000 by source of fuels used in generation (Figure III-19).

Capacity and generation estimates for conventional hydroelectric and steam-electric (nuclear and fossil-fueled) plants are projected to increase by about 384 percent during the 1975-2000 period. This reflects

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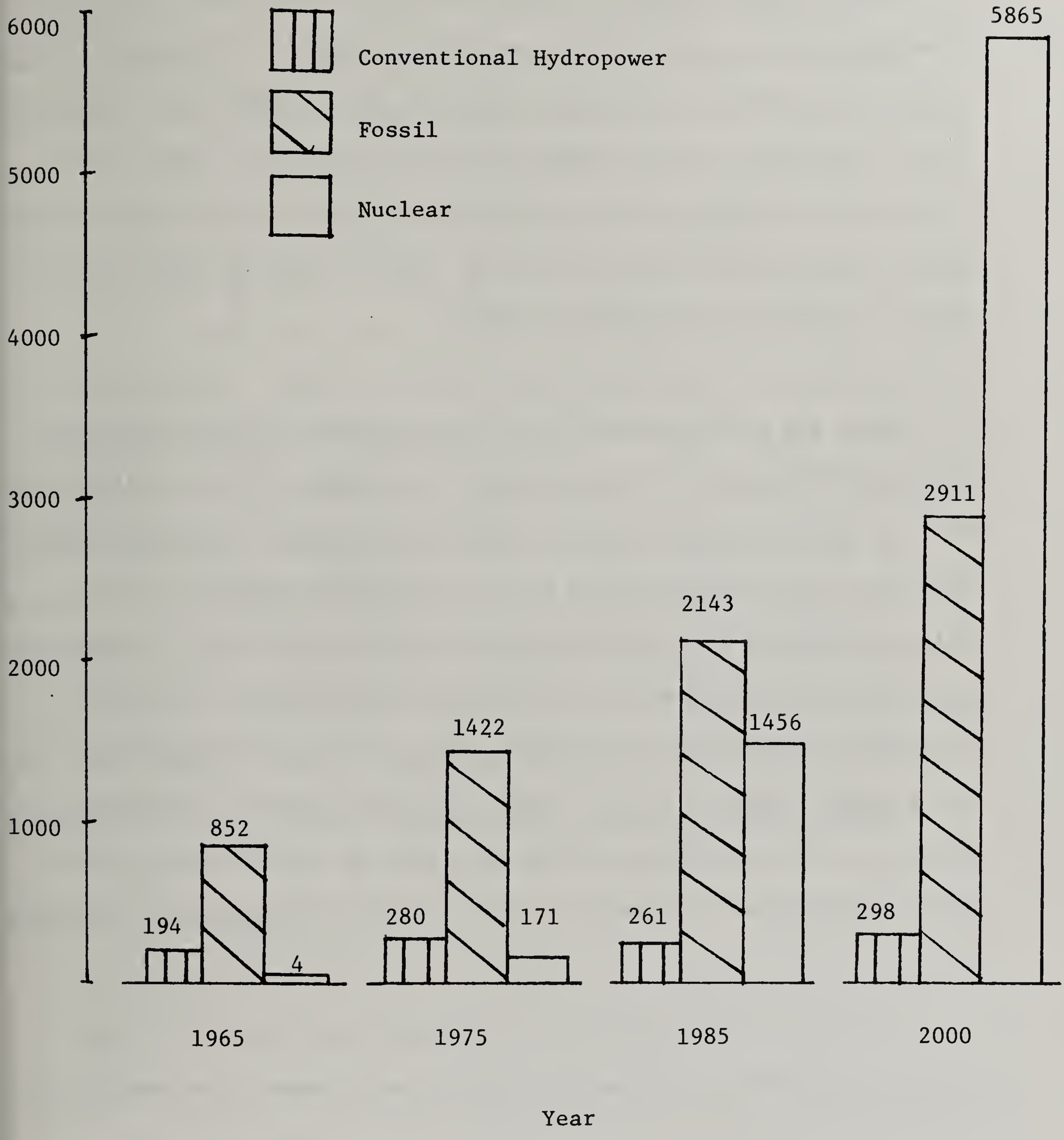
* A comparison of the different energy projections and the related implications are made later in this Chapter.

Figure III-19

ELECTRIC POWER GENERATION BY FUEL SOURCE



an average annual growth of about 6 percent. The historical increase in electrical generation has been about 7 percent annually for the Nation.

The projected increase is not evenly distributed among types of generating plants. For example, conventional hydroelectric plants are projected to generate only about 6 percent more in 2000 than they did in 1975. Conversely, nuclear power plants are projected to generate 5.9 million GWh in 2000 or about 34 times their generation in 1975. Fossil-fueled plants are projected to provide about 2.9 million GWh in 2000 or about 2 times their generation in 1975.

There are several significant factors which could substantially alter projected electric load growth. For example, if energy independence is realized, there must be a significant switch from liquid fuels now used in the transportation sector to electric powered vehicles. Also, if existing air quality standards are met, stack gas cleaners will be required on more than half of the coal fired plants. If sulfur scrubbers are installed the plants' output would be reduced 6-8 percent and a need to build additional plants would be created. Conversely, there are several emerging technologies such as fluidized-bed boilers which could reduce the load by eliminating the need for sulfur scrubbers.

Total Energy Production and Electric Power Generation

It is essential to distinguish between total energy consumption and direct requirements for electric generation because of significant differences in fuel efficiencies, in substitutions of fuels, and in the water requirements for both different fuels and different conversion processes. For example, total energy production in 1975 was 92 percent by fossil fuels, 5 percent by hydro, and less than 3 percent by nuclear fuels (Table III-43). However, electric power generation in 1975 was only 76 percent by fossil fuels, 15 percent hydro, and 9 percent nuclear. In 1975 the fossil fuel sources dominated both gross energy and electric power generation. However, by 2000 fossil fuel will be used largely for other types of energy conversion (65 percent of gross energy consumption) while nuclear fuels will be the primary source (65 percent) of electric power generation. The portion of total energy consumption used to generate electricity is projected to increase from 21 percent in 1975 to 62 percent in 2000, indicating the growing importance of the electric utility system in the Nation (Figure III-20). The projected uses of fuel are controversial, but the parameters used for these projections are presented in the appendix on Energy and Related Water Requirements.

Water Use Variations

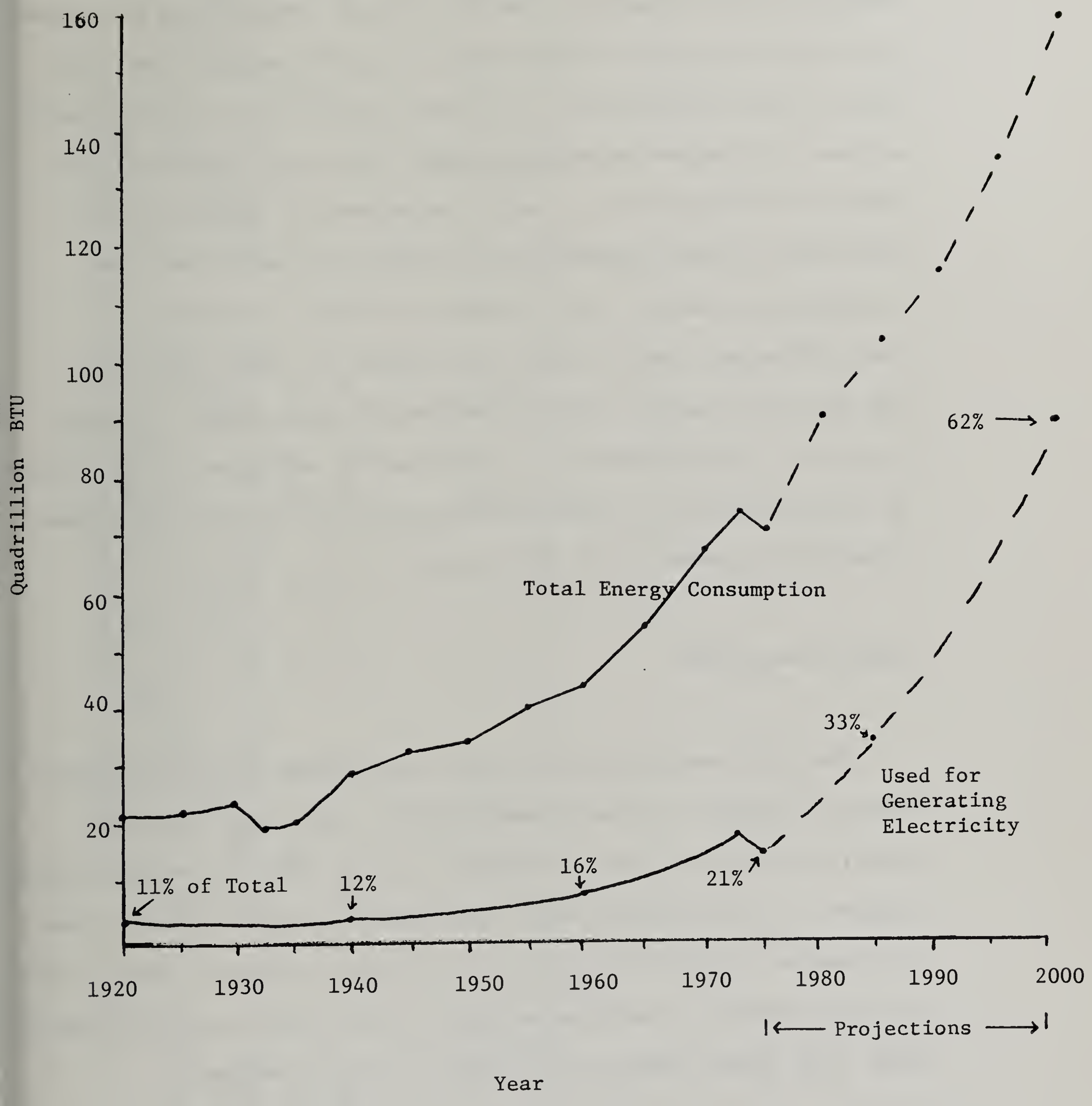
Water withdrawal requirements for meeting energy consumption expectations will depend mainly on the composition of fuels and conversion

Table III-43
ESTIMATES OF TOTAL ENERGY CONSUMPTION AND ELECTRIC POWER GENERATION BY SOURCE OF FUEL - 1975, 1985, 2000

Type of Fuel Used	Gross Energy Consumption						Electric Power Generation					
	1975		1985		2000		1975		1985		2000	
	Quads	Percent	Quads	Percent	Quads	Percent	1000 gwh	Percent	1000 gwh	Percent	1000 gwh	Percent
Fossil	66.2	92	87.0	85	105.6	65	1,422	76	2,143	56	2,911	32
Nuclear	1.8	3	11.8	11	46.1	28	171	9	1,456	38	5,865	65
Hydro	3.3	5	3.3	3	4.3	3	281	15	261	6	298	3
Other	.3	1	1.0	1	6.5	4	-	-	-	-	-	-
TOTAL	71.6	100	103.1	100	162.5	100	1,873	100	3,861	100	9,074	100

Figure III- 20

UNITED STATES ENERGY CONSUMPTION, 1920-2000



methods used (Table III-44). For example, high use levels of nuclear sources of energy will result in higher withdrawals and consumption of water relative to the energy produced. In 2000 the average year withdrawals of water for electric generation are estimated at 642 bgd (80 percent) nuclear and 15.9 bgd (20 percent) fossil for electric energy production of 65 percent nuclear and 32 percent fossil because of the higher water requirements for nuclear fuel generation (Tables III-44 and III-45). Greater dependence on fossil and other fuel sources except geothermal would reduce water withdrawals and consumption for energy. Also, within the fossil fuel sources for energy different mixes of fuels would change the water requirements with petroleum sources requiring considerably more water for energy than coal. The preponderance of water use for steam-electric generation (94 percent) relative to fuels production and refining for total energy production is summarized in Table III-45.

Regional Variations

Electric power generation varies substantially among regions with respect to sources of power (Table III-46). The largest producing region in 1975 was the Ohio followed closely by the other industrialized regions -- South Atlantic-Gulf, Mid-Atlantic, and Great Lakes. These four regions generated 51 percent of the Nation's electric power in 1975 and will continue to generate one half of the Nation's electric power in 2000. The fastest growth rates in electric power generation

Table III-44

ESTIMATES OF WATER WITHDRAWALS FOR TOTAL ENERGY CONSUMPTION AND ELECTRIC POWER GENERATION BY SOURCE OF FUEL - 1975, 1985, 2000; AVERAGE YEAR

Type of Fuel Used	Total Energy Consumption						Electric Power Generation					
	1975		1985		2000		1975		1985		2000	
	BGD	Percent	BGD	Percent	BGD	Percent	BGD	Percent	BGD	Percent	BGD	Percent
Fossil	76.9	82	45.0	45	20.8	24	71.8	81	40.2	42	15.9	20
Nuclear	17.3	18	54.7	55	64.2	76	17.3	19	54.7	58	64.2	80
Hydro	-	-	-	-	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	94.2	100	99.7	100	85.2	100	89.1	100	94.9	100	80.1	100

Table III-45

SUMMARY OF WATER WITHDRAWALS FOR TOTAL ENERGY PRODUCTION BY WATER RESOURCES REGIONS AND TYPE OF USE - 1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Region	For Mining Fuels*			For Refining Petroleum*			For Steam Electric Generation			For Total Energy Production**		
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000
New England	0	0	0	16	8	5	1,263	1,069	375	1,279	1,077	380
Mid-Atlantic	21	19	22	562	228	137	7,463	7,130	4,657	8,046	7,377	4,816
South Atlantic-Gulf	68	85	86	28	32	25	12,768	12,912	13,952	12,864	13,029	14,063
Great Lakes	14	18	21	687	141	95	24,362	22,689	16,061	25,063	22,848	16,177
Ohio	183	288	334	114	52	48	21,022	21,008	10,574	21,319	21,348	10,956
Tennessee	8	14	21	0	0	0	4,799	5,738	4,581	4,807	5,752	4,602
Upper Mississippi	20	33	48	50	36	33	7,644	6,347	3,537	7,714	6,416	3,618
Lower Mississippi	644	841	1,065	441	220	150	4,175	9,313	16,687	5,260	10,374	17,902
Souris-Red-Rainy	4	4	4	0	0	0	82	23	0	86	27	4
Missouri	144	198	236	91	36	29	3,540	5,834	4,938	3,775	6,068	5,203
Arkansas-White-Red	172	190	185	74	75	94	498	1,026	1,012	744	1,291	1,291
Texas-Gulf	837	902	930	312	496	479	724	1,000	2,262	1,873	2,398	3,671
Rio Grande	153	151	147	0	0	0	34	16	10	187	167	157
Upper Colorado	68	97	171	4	1	1	101	157	201	173	255	373
Lower Colorado	7	6	8	1	1	0	68	150	154	76	157	162
Great Basins	1	1	1	8	7	7	33	65	82	42	73	90
Pacific Northwest	3	4	6	11	12	15	260	203	580	274	219	601
California	193	235	217	123	147	100	42	158	367	358	540	684
Alaska	12	133	342	1	1	1	26	17	22	39	151	365
Hawaii	0	0	0	5	6	6	0	0	0	5	6	6
Caribbean	0	0	0	0	0	0	0	0	0	0	0	0
Total, Regions 1-18	2,540	3,086	3,502	2,522	1,492	1,218	88,878	94,838	80,030	93,940	99,416	84,750
Total, Regions 1-21	2,552	3,219	3,844	2,528	1,499	1,225	89,904	94,855	80,052	94,984	99,573	85,121

* Water requirements for these sectors are presented in Chapters 4 and 7 on manufacturing and mining, respectively.

** The difference in water withdrawals for mining fuels plus refining petroleum and total production is that used for steam-electric power generation.

Table III-46
SUMMARY OF ESTIMATED ELECTRIC POWER GENERATION BY SOURCE OF POWER BY WATER RESOURCES REGION - 1975, 1985, 2000
(1,000 GIGIWATT HOURS)

Region	Total Generation			Fossil Fuels			Nuclear Fuels			Hydro Power		
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000
New England	67	126	295	44	52	90	20	72	202	2	2	3
Mid-Atlantic	200	406	903	158	191	249	37	211	650	5	4	4
South Atlantic-Gulf	238	675	1,773	190	329	748	30	331	1,010	18	15	15
Great Lakes	209	374	842	148	156	186	35	198	635	26	21	21
Ohio	304	506	1,057	299	424	522	0	75	527	5	6	8
Tennessee	68	163	263	46	39	57	3	109	191	19	15	15
Upper Mississippi	114	250	668	88	126	156	25	122	509	1	1	1
Lower Mississippi	54	121	366	53	80	72	0	40	293	1	1	1
Souris-Red-Rainy	1	1	0	1	1	1	0	0	0	0	0	0
Missouri	75	187	449	50	138	209	6	35	226	19	14	14
Arkansas-White-Red	73	165	404	61	115	102	5	44	297	7	6	6
Texas-Gulf	124	275	825	123	216	205	0	58	618	1	1	1
Rio Grande	11	5	27	11	5	2	0	0	23	1	1	1
Upper Colorado	24	58	91	23	57	74	0	0	13	1	1	3
Lower Colorado	33	65	103	24	48	51	0	7	43	9	9	9
Great Basins	4	25	124	3	10	9	0	14	115	1	1	1
Pacific Northwest	138	189	409	6	10	18	3	45	235	129	134	156
California	121	227	344	79	115	92	6	84	220	36	29	32
Alaska	1	3	15	1	2	7	0	0	0	1	1	8
Hawaii	5	10	26	5	10	26	0	0	0	0	0	0
Caribbean	10	31	94	10	21	35	0	0	0	0	0	0
Total, Regions 1-18	1,857	3,816	8,939	1,406	2,110	2,842	171	1,446	5,807	280	260	290
Total, Regions 1-21	1,872	3,861	9,074	1,422	2,143	2,911	171	1,456	5,865	281	261	298

by 2000 (6 times 1975 generation or greater) will occur in the Upper and Lower Mississippi, Missouri, Arkansas-White-Red, Texas-Gulf, Great Basin, Alaska, and Caribbean Regions. Growth in fossil fuel generation by 2000 of more than 3 times 1975 generation will occur in the South Atlantic-Gulf, Missouri, Upper Colorado, Great Basin, Pacific Northwest, Alaska, Hawaii, and Caribbean Regions. The greatest growth in nuclear generation by 2000 (more than 50 times 1975) will occur largely in those regions with little or no nuclear generation capacity in 1975, namely the Ohio, Tennessee, Lower Mississippi, Arkansas-White-Red, Texas-Gulf, and Pacific Northwest among others. Most regions, except New England, Ohio, Pacific Northwest, and Alaska, can expect declines in hydropower generation over the 25 years 1975 to 2000.

Water Requirements for Electric Generation (Cooling)

In hydroelectric plants the power produced is directly proportional to the quantity of water flowing through the turbine and the head. There is little consumptive use of water except through water surface evaporation. Pumped storage projects also consume little water. The principal use of water for electrical energy production is in steam generating plants for condenser cooling purposes. Although essentially no water is used consumptively in the condensers, losses occur when the condenser flows are either returned to the source bodies of water at higher temperatures or passed through cooling towers or cooling ponds. The amount of water required for condenser flows depends upon the type of plant, its efficiency, and the temperature rise through the condensers.

Withdrawal and consumptive uses of water for electric power generation are directly related to the efficiency of the conversion of the energy in fuel to electricity. A measure of generating plant efficiency is its heat rate. Heat rate is the amount of fuel energy measured in terms of its heat equivalent that is required to produce one kilowatt-hour of net electrical energy. Plant efficiencies improved from about 21 percent (16,500 Btu/kilowatthour (kWh)) in 1938 to 33 percent (10,500 Btu/kWh) in 1965. Only slight increases in efficiencies are projected through the year 2000. These increases will be less if more stringent pollution control requirements are initiated. Fossil plants which require stack emission control equipment would have about 5 percent higher heat rates than those without such equipment. Heat rates for modern steam-electric plants placed in operation before the year 2000 are expected to have average heat rates varying between 9,600 and 10,500 Btu per kWh (Table III-46).

There are several factors which influence heat rate. One is the temperature and pressure of the steam leaving the boiler. Modern fossil-fueled plants are usually designed to operate at temperatures of about 1,000° F. and 2,400-3,500 pounds per square inch guage (p.s.i.g).

Nuclear plants, because of safety considerations, are designed to operate at temperatures and pressures lower than fossil plants. Consequently, their efficiencies are lower than fossil plants and a larger portion of the heat in the boiler or working water of nuclear plants is discharged to the condenser and cooling water. Modern nuclear plants discharge about 30 percent more heat per unit of generation to the cooling water than comparable fossil-fueled plants. It is anticipated that breeder and higher temperature gas cooled reactors will have efficiencies approaching those of new fossil plants.

Cooling water requirements are directly related to the amount of residual heat discharged to the condenser and the type of cooling. Cooling water requirements by region are given in Table III-47 for freshwater and III-48 for saline water. Additional background information is given in the appendix on Energy and Related Water Requirements.

The principal types of cooling systems now in use or proposed for steam-electric plants are: once-through using fresh or saline water, cooling ponds including spray ponds, wet cooling towers, and dry cooling towers. Rivers have been used extensively as sources of cooling water where the streamflows provide a natural conveyance and dissipating medium for waste heat discharged. Due to the large magnitude of flows required to absorb and dissipate the waste heat from the large generating complexes projected for the future and the possible adverse effects of the heated discharges on the water quality, the number of river sites

Table III-47

SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION FOR STEAM-ELECTRIC GENERATION BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR

(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	1,263	1,069	375	21	18	167
Mid-Atlantic	7,463	7,130	4,657	103	224	644
South Atlantic-Gulf	12,768	12,912	13,952	153	722	1,857
Great Lakes	24,362	22,689	16,061	175	497	1,384
Ohio	21,022	21,008	10,574	324	656	1,692
Tennessee	4,799	5,738	4,581	42	231	417
Upper Mississippi	7,644	6,347	3,537	129	352	1,079
Lower Mississippi	4,175	9.313	16,687	54	118	291
Souris-Red-Rainy	82	23	0	1	0	0
Missouri	3,540	5,834	4,938	68	239	637
Arkansas-White-Red	498	1,026	1,012	89	237	457
Texas-Gulf	724	1,000	2,262	99	270	994
Rio Grande	34	16	10	18	9	5
Upper Colorado	101	157	201	38	106	151
Lower Colorado	68	150	154	63	134	126
Great Basins	33	65	82	3	42	52
Pacific Northwest	260	203	580	13	104	344
California	42	158	367	25	101	242
Alaska	26	17	22	0	2	5
Hawaii	0	0	0	0	0	0
Caribbean	0	0	0	0	0	0
Total, Regions 1-18	88,878	94,838	80,030	1,418	4,060	10,539
Total, Regions 1-21	89,904	94,855	80,052	1,418	4,062	10,544

Table III-48
SUMMARY OF SALINE WATER WITHDRAWALS AND CONSUMPTION FOR STEAM-ELECTRIC POWER GENERATION BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	4,831	14,604	10,161	47	108	293
Mid-Atlantic	16,997	28,634	26,208	96	305	813
South Atlantic-Gulf	7,009	14,976	20,239	62	233	904
Great Lakes	0	0	0	0	0	0
Ohio	0	0	0	0	0	0
Tennessee	0	0	0	0	0	0
Upper Mississippi	0	0	0	0	0	0
Lower Mississippi	320	1,590	10,181	2	10	63
Souris-Red-Rainy	0	0	0	0	0	0
Missouri	0	0	0	0	0	0
Arkansas-White-Red	0	0	0	0	0	0
Texas-Gulf	4,139	4,950	10,371	37	45	199
Rio Grande	0	0	0	0	0	0
Upper Colorado	0	0	0	0	0	0
Lower Colorado	0	0	0	0	0	0
Great Basins	0	0	0	0	0	0
Pacific Northwest	0	7	10,652	0	0	65
California	10,157	22,090	24,658	55	125	155
Alaska	67	44	420	0	0	2
Hawaii	1,085	2,005	3,637	3	8	20
Caribbean	1,124	2,337	2,288	9	35	149
Total, Regions 1-18	43,453	86,851	112,470	299	826	2,494
Total, Regions 1-21	45,729	91,237	118,815	311	869	2,663

suitable for new once-through cooling installations is limited. Where available large lakes, reservoirs, estuaries, and oceans may be used for cooling when such use does not violate water quality standards nor other planned uses of these water bodies.

Where the availability of water and water quality standards preclude the use of surface waters for once-through cooling ponds or cooling towers are generally employed for the dissipation of waste heat. In water-deficient areas sewage treatment plant effluents have been used in some cases to provide water make-up requirements.

Cooling method selections for the Second Assessment studies assumed cooling towers for most new plants. However, cooling ponds, once-through cooling, and combinations of types of cooling were projected in some cases. Dry cooling towers were projected for some plants located in water-scarce areas. The electric power industry is expected to continue to deviate sharply from historic practices of using once-through cooling by increased use of cooling ponds or wet cooling towers for heat disposal.

Water requirements of steam-electric plants, for purposes other than condenser cooling, are similar to those of other commercial buildings such as air conditioning, sanitary, and fire protection requirements. Sulfur scrubbers have been used on experimental and full size plants for several years. Although these facilities are designed to remove nitrogen oxides, sulfur oxides, particulates, and other impurities their primary purpose is to remove sulfur dioxide. If stack emission control standards are strictly enforced more than half of the coal fired electric generating plants will need sulfur scrubbers or equivalent equipment.

Consumptive water use required for a modern 1,000 megawatt coal fired steam-electric plant using wet cooling towers and operating at 70 percent plant factor is estimated at about 9 MGD for cooling and about 1 MGD for sulfur removal. Water requirements for sulfur removal will be about 135 billion gallons in the year 2000 or an average of 370 MGD. Most of this water will be lost to the atmosphere, and the remainder will return to the ground water through seepage from the settling ponds. This amounts to about 3 percent of the projected total consumptive freshwater use by both fossil and nuclear-fueled steam-electric plants in 2000.

Several emerging technologies could significantly reduce water requirements in steam-electric plants. One is fluidized-bed boilers which allow lime to be added to coal in the boiler and require no sulfur removal equipment and no additional water for stack gas control. There is a reasonable possibility that this type boiler will be developed and put into production during the next 10 years. If this occurs water use for sulfur emissions control would be less than the 370 MGD stated above.

Related Resource Considerations in Energy Production-Consumption

All discharges of heated water will contribute to physical and biological changes in the receiving body. These changes can be beneficial, detrimental, or insignificant depending upon the ecology of the particular water body and the amount and temperature of the discharges. The addition of heat to water bodies may increase rates of chemical solubility and biochemical reactions causing effects on aquatic organisms in the area of higher temperatures. Another possibility arising from adding heat to a water body is stratification because of the reduced density of the water at increased temperatures. The difference in density with a relatively few degrees difference in temperature is often sufficient to cause the water to flow as separate and distinct layers.

Sulfur oxides have been the most extensive air pollutant from electric utility installations. Atmospheric sulfur oxides originate during the combustion of sulfur-bearing coal, oil, and, to a very much smaller extent, natural gas. The rate at which pollutants are emitted from a power plant burning fossil-fuel depends upon the type and quality of fuel burned, design of the boiler, method of combustion, and other factors. The sulfur occurs primarily in organic and pyritic forms and is transformed by the combustion reaction into sulfur dioxide (SO_2) and sulfur trioxide (SO_3).

The ash is a complex of noncombustible materials, which end up as slag, dry bottom ash, and fly ash. The use of low sulfur coal -- coal containing less than 1 percent sulfur by weight -- is the simplest method of reducing sulfur dioxide emissions at coal-burning power plants, but the supplies of low-sulfur coal are often either committed to steel production and export or situated in deposits far removed from existing power plants. Air quality standards can be maintained even with high sulfur coal if devices such as flue gas desulfurization systems are used.

Comparison of National, State-Regional, and Other Futures

The generally unexpected developments in the Nation's energy situation during the conduct of this Assessment produced a number of alternatives energy future projections. The major projections, in addition to the National Future for this Assessment, were made by the Federal Energy Administration (FEA) and the U.S. Department of Commerce (DOC). Summaries of these alternative futures are presented for the types of fuel used by the energy sector of the economy (Table III-49) and by the using sector (Table III-50). Generally the projections for 1985 and 2000 which were

Table III-49
UNITED STATES ENERGY RESOURCES CONSUMPTION PROJECTIONS BY FUEL TYPES
(TRILLION BTU)

Fuel Type	1985			2000		
	WRC*	FEA	DOC	WRC*	ERDA	DOC
Coal	21.3	20.6	18.7	34.8	41.5	39.0
Petroleum	45.6	41.5	38.1	51.2	39.4	26.1
Natural Gas	20.1	24.2	18.8	19.6	20.4	18.4
Nuclear	11.8	8.7	7.9	46.1	29.0	20.3
Oil Shale and Other	0.9	-	0.7	5.7	2.8	5.0
Hydro and Geothermal	3.9	3.9	4.0	6.1	9.2	7.9
TOTAL	103.6	98.9	87.2	163.5	142.3	116.7

* Estimated for the Second National Water Assessment for the purpose of estimating water requirements.

WRC - Water Resources Council
FEA - Federal Energy Administration (now in the Department of Energy)
DOC - Department of Commerce
ERDA - Energy Resource Development Administration (now in the Department of Energy)

Table III-50

UNITED STATES ENERGY RESOURCE CONSUMPTION BY USER SECTORS (TRILLION BTU)

User Sector	1985			2000		
	WRC*	FEA	DOC**	WRC*	ERDA	DOC**
Household and Commercial	16.5	14.8		17.0	19.2	
Industrial	22.8	27.1		25.3	36.8	
Transportation	23.6	23.2		28.8	24.1	
Electrical	39.1	33.7		78.6	61.3	
Synthetics	1.5	0.1		13.9	4.0***	
TOTAL	103.5	98.9	87.4	163.4	142.4	116.0

* Estimate from the Second National Water Assessment (Bureau of Mines source).

** Not disaggregated.

*** Portions distributed to other sectors. The total should be 142,340 trillion BTU.

WRC - Water Resources Council

FEA - Federal Energy Administration (now in the Department of Energy)

DOC - Department of Commerce

ERDA - Energy Resource Development Administration (now in the Department of Energy) made for this Assessment are higher than those made later by FEA and DOC. This Assessment also includes substantially higher dependence or nuclear generation assumptions than the later estimates.

The differences in water requirements between the National Future and State-Regional Future are not significant at the National level. However, there are variations at the regional and aggregated subregional level which are significant, and these are discussed in the regional reports. In reviewing all of the futures' projections thate is a potential for water requirements to be less for the lower energy consumption levels. Thus, the National Future is a conservative estimate or the worst case situation for water for energy needs.

Summary

Energy permeates all aspects of life in the United States. By far the largest user of water for energy production is the electric utility industry. In 1975 water withdrawals for electric power accounted for 94 percent of all withdrawals for fuel mining and energy production and 26 percent of total U.S. water withdrawals. Although the production of electricity requires large withdrawals it accounted for only 1 percent of total water consumption in 1975. Presently only 2 percent of water withdrawn for steam-electric is consumed.

Since consumption is low, water supply for energy resources development will be of concern only in a few areas of the United States. Energy production, however, will continue to receive strong National attention and the striving for energy self-sufficiency will result in the development of more domestic sources of energy. Problems associated with water for energy and heat discharged to the Nation's waters will require considerable National policy and management attention in the near future.

PART III

CHAPTER 7

WATER REQUIREMENTS FOR MINERAL PRODUCTION AND RELATED RESOURCE CONSIDERATION

The mineral industry has relatively minor water needs compared to large users such as agriculture. The mineral industry withdrew an average of 7.1 bgd or 2.1 percent of all withdrawals in 1975. Water withdrawals for minerals mining is projected to increase about 61 percent by 2000 when withdrawals of 11.3 bgd make up 3.7 percent of total withdrawals. Water withdrawals for minerals mining will grow concurrent with mineral consumption without noticeable improvements in efficiencies or recycling. For example, water withdrawals for all off-stream uses are projected to decline 9 percent from 1975-2000 with the largest decline of 62 percent in manufacturing while mineral withdrawals increase by 61 percent (Table III-51).

Consumptive uses of water for minerals mining are expected to remain fairly constant at 31-32 percent of withdrawals over the 25 years 1975-2000. Nonmetals mining is the largest withdrawal use in the minerals industry at 52 percent of the industry total of withdrawals. Consumptive use in nonmetals mining is only 28 percent of the total for the U.S. and territories.

Fuels mining and processing withdraw about 36 percent of the water withdrawn for minerals mining but consumptive uses (53.54 percent of

TABLE III-51
SUMMARY OF FRESHWATER WITHDRAWAL AND CONSUMPTIVE
USES IN THE MINERAL INDUSTRY BY MINERAL CATEGORY - 1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Mineral Category	Withdrawals						Consumption					
	1975		1985		2000		1975		1985		2000	
	MGD	Percent	MGD	Percent	MGD	Percent	MGD	Percent	MGD	Percent	MGD	Percent
Nonmetals	3686	52	4560	52	6123	54	543	25	686	25	1021	28
Fuels	2552	36	3219	36	3844	34	1359	62	1688	61	2075	58
Metals	817	12	1053	12	1361	12	294	13	403	14	513	14
Totals	7055	100	8832	100	11328	100	2196	100	2777	100	3609	100

withdrawals) are 62 percent of total minerals mining consumption. Metals mining water withdrawals and consumption is quite stable at about 12-13 percent of the total.

Water is used in the minerals industry for mining metals, nonmetals, and fuels. Nonmetals consist of lime, clay, barite, phosphate, rock, salt, rock wool, pumice, sand, gravel, and stone. Fuels comprise coal, oil shale, petroleum, natural gas, natural gas liquids and uranium. Metals include iron, lead, zinc, manganese, gold, silver, copper, and molybdenum.

A trend toward large-scale mineral operation, brought about by the interrelated factors of mining and processing of lower grade ores that require higher capital outlays and longer term market commitments, will generally require more water per unit of production in the future. Also, larger quantities of water will be required to recover additonal minerals, especially fuels which require injection or flooding techniques for high recovery operations. Solution mining techniques are needed to recover certain deep minerals not amenable to underground mining. Leaching methods are needed to recover minerals too low in grade for current systems and newer processes are needed to meet environmental goals. These increased water withdrawals and consumption may be reduced through continued research and applications leading to more water recycling and other conservation measures in minerals mining.

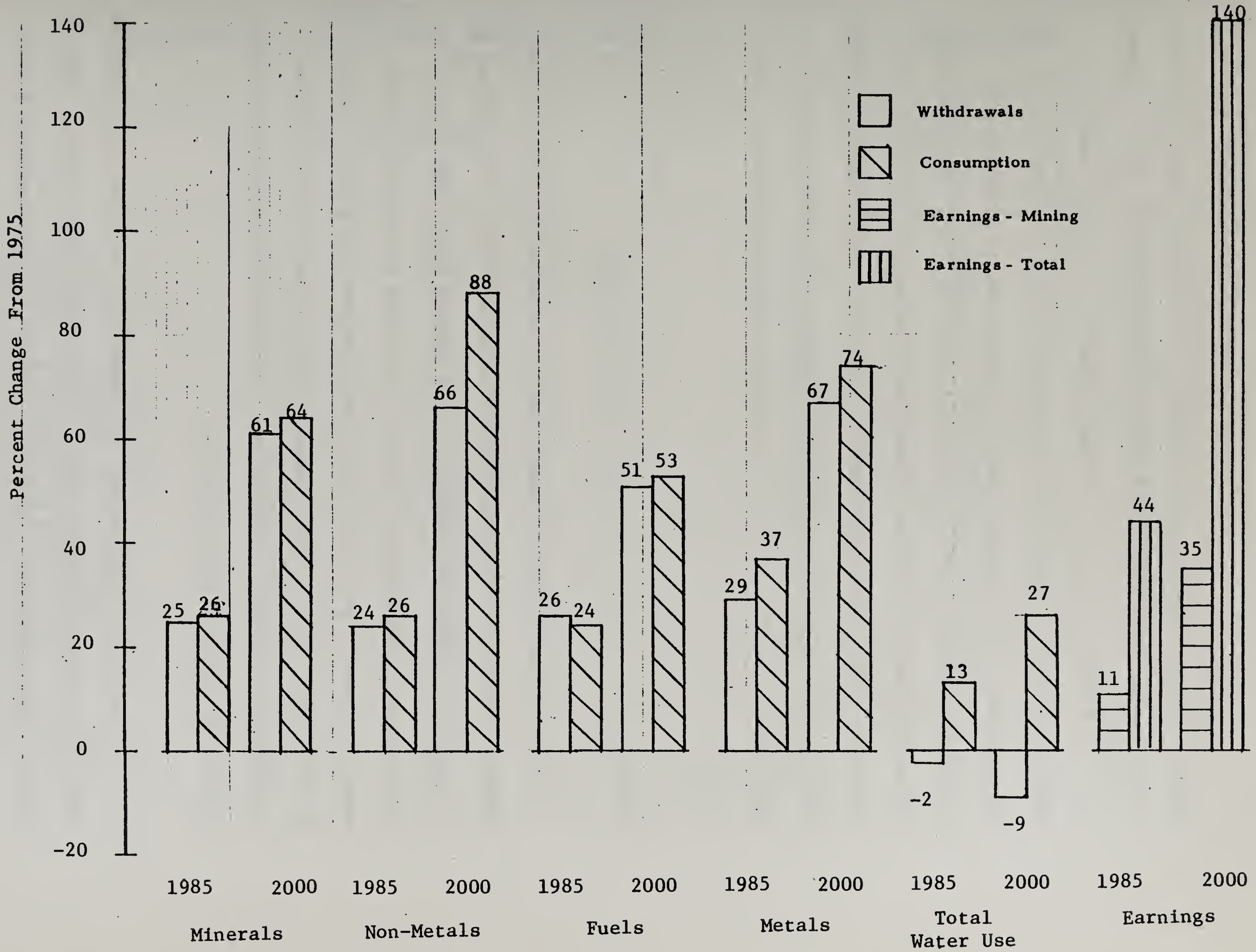
Water Uses by the Mineral Industries

Water uses in the mineral industries are derived from the final consummer activities each industry supports and depends upon. For example, nonmetals mining of lime, clay, phosphate, sand, gravel, and stone is heavily dependent on the levels and types of construction activities. Fuels production is dependent on the different types of energy demanded and the variations in supplies available at different times and locations for economic or environmental reasons.

These variations affect the location of energy production facilities and the balance between domestic and import supplies. Requirements for water for metals mining are related directly to mining and smelting activity levels.

Water withdrawals and consumption are projected to increase much faster in the nonmetals sector (66 and 88 percent respectively by 2000) than in the metals or fuels production sector. However, all mining activities are projected to use water much more freely than manufacturing agriculture, and electric generation in both absolute quantities and relative to less than average performance of the industry in certain indicator areas like earnings (Figure III-21). Projections for increased water uses in mining are also related to the changing technologies available to the mining industry to avert water quality problems and

FOR MINERALS, FOR TOTAL WATER USE, AND FOR TOTAL AND
MINING EARNINGS 1975-1985 and 1975-2000



changing corporate and industry activity. For example, about 89 percent of all water used in fuels production (2.27 bgd in 1975) is for secondary recovery of petroleum largely through injection. Typical secondary petroleum operations use about 7.7 barrels of water for each barrel of oil recovered. This ranges from as little as one to as much as 28 barrels of water per barrel of crude oil with the older, more depleted fields requiring the heaviest injections of water per barrel of oil. Larger oil imports or larger domestic coal and nuclear fuel sources will tend to reduce water requirements for domestic fuel production -- a large part of which will be from secondary recovery processes in the future.

Nonmetals

Construction materials (sand, gravel, and stone) account for the largest proportion of nonmetallic minerals production in all regions and for most of the water withdrawals in the eastern two-thirds of the conterminous United States. Except in the Lower Mississippi Region, nonmetals production uses 75 percent of all water withdrawn for mineral production. In the western regions where mining occurs and the Lower Mississippi Region nonmetals mining withdraw only about 20 percent of waters used in the mineral industry (Table III-52).

The largest wateruse regions for nonmetallic mineral production are those with large and growing industrial and population centers. Nonmetals mining operations are directly related to population and growth

Table III-52
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION FOR NONMETALS MINING BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	87	112	49	11	16	20
Mid-Atlantic	424	514	662	56	69	88
South Atlantic-Gulf	1105	1446	1983	158	207	284
Great Lakes	451	563	734	62	74	99
Ohio	308	372	471	34	50	64
Tennessee	86	108	144	12	15	20
Upper Mississippi	268	334	427	35	45	57
Lower Mississippi	141	157	242	36	38	114
Souris-Red-Rainy	4	5	6	1	1	1
Missouri	91	116	143	10	12	14
Arkansas-White-Red	222	209	289	52	46	73
Texas-Gulf	187	198	275	20	20	29
Rio Grande	28	46	64	14	29	43
Upper Colorado	45	68	127	6	10	20
Lower Colorado	27	40	53	8	19	44
Great Basin	22	36	58	3	7	12
Pacific Northwest	57	75	91	8	9	14
California	98	118	151	13	14	19
Alaska	3	5	7	0	0	0
Hawaii	1	1	1	0	0	0
Caribbean	31	37	46	4	8	6
Total, Regions 1-18	3651	4517	6069	539	681	1015
Total, Regions 1-21	3686	4560	6123	543	686	1021

with few exceptions. The South Atlantic-Gulf (the largest user) and the Lower Mississippi Regions are growing rapidly, and most of the large nonmetal mining water use is attributable to phosphate and sulfur mining industries in these regions, largely in Florida and Louisiana, respectively. Consumption is only about 14 percent of withdrawals for this industry.

Water use in the year 2000 for the mining industry will follow the same patterns existing in 1975. The South Atlantic-Gulf, Great Lakes, Mid-Atlantic, Ohio, Upper Mississippi, and Arkansas-White-Red will be the largest users with increases of 80 percent in the South Atlantic-Gulf Region and more than 1.5 times in the other leading regions. Although the construction industry is expected to grow with population increases, there does not appear to be any dramatic shifts in uses or significant water problems associated with nonmetals mining. Environmental concerns and other legal considerations for offshore dredging of construction materials versus development on or near such deposits may generate local changes in water needs, especially in marine and lake coastal areas. Technological improvements in phosphate and sulfur production are expected to offset higher environmental standards with little influence on water uses in Florida and the Gulf Coast areas.

Fuels Production

The mining and primary processing of fuels (coal, oil, and gas) is considered with the minerals group for the Second Assessment although econdary processing and conversion to basic energy, direct consumption, nd conversion to electricity are included in manufacturing under etroleum refining and steam electric generation in earlier sections of his report. The conversion function is quite large, but indications re that other fuel sources such as nuclear may reduce the conversion unction, especially of petroleum. Increasing emphasis on reducing etroleum imports may substantially increase the use of coal for energy onversion with corresponding savings in water requirements vis-a-vis he use of nuclear alternatives (see Chapter 5 on Water for Energy).

Fuels production withdraws only onethird of the total water withdrawn or minerals production for 1975, 1985, and 2000 (Table III-53). owever, the consumption rate for fuels production is about 53 percent f withdrawals with the result that total consumption of water for fuels roduction is 62 percent of that for all minerals metals, nonmetals, nd fuels (Table III-51). The ratio of consumption to withdrawals is ighest in the fuels sector, about 3.5 times that of nonmetals. The eading water use regions for fuels production are the Texas-Gulf, Lower ississipppi, California, Ohio, Arkansas-White-Red, Rio Grande, and issouri Regions. Excluding the Ohio and Missouri Regions these Regions re the Nation's leading producers of oil and gas and withdrew an average f 2 bgd or 78 percent of all freshwater withdrawals for fuels production in 1975.

TABLE III-53
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN FUELS PRODUCTION INDUSTRIES BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	0	0	0	0	0	0
Mid-Atlantic	21	19	22	12	11	12
South Atlantic-Gulf	68	85	86	55	66	64
Great Lakes	14	18	21	8	10	11
Ohio	183	288	334	57	82	96
Tennessee	8	14	21	1	3	4
Upper Mississippi	20	33	48	4	6	9
Lower Mississippi	644	841	1065	167	212	209
Souris-Red-Rainy	4	4	4	2	2	2
Missouri	144	198	236	96	122	142
Arkansas-White-Red	172	190	185	114	128	130
Texas-Gulf	837	902	930	532	564	598
Rio Grande	153	151	147	86	90	88
Upper Colorado	68	97	171	38	56	111
Lower Colorado	7	6	8	5	4	5
Great Basin	1	1	1	1	1	1
Pacific Northwest	3	4	6	2	2	4
California	193	235	217	169	210	192
Alaska	12	133	342	11	120	308
Hawaii	0	0	0	0	0	0
Caribbean	0	0	0	0	0	0
Total, Regions 1-18	2540	3086	3502	1348	1568	1767
Total, Regions 1-21	2552	3219	3844	1359	1688	2075

The Ohio and Missouri Regions are the leading coal producing regions, withdrawing about 327 mgd or 15 percent of the fuels total. Together these seven regions withdraw 93 percent of all water used in fuels production and consume 90 percent of the waters consumed in fuels production.

By the year 2000 some changes are projected to occur. Texas-Gulf withdrawals will grow only 11 percent, but the Lower Mississippi will become the largest withdrawal user in oil and gas recovery and processing, especially in the rapidly expanding secondary recovery through injection and flooding of older wells.

However, consumptive uses will remain very high in the Texas-Gulf Region (double that in the Lower Mississippi Region) at 64 percent of withdrawals for fuels production. The older petroleum fields in this region will increase water consumption in secondary recovery operations. These continued high levels of consumption will also be expected to occur in the Arkansas-White-Red, Rio Grande, and California Regions with a consumption withdrawal ratios around 75 percent.

Alaska will be the fastest growing region in terms of both withdrawals and consumption for fuels production -- primarily petroleum. Water withdrawals and consumption for fuels production in Alaska are expected to increase 28 times from 1975-2000.

The year 2000 will likely see substantial increases in water uses for coal production in the Ohio and Missouri Regions, an increase of about 75 percent in withdrawals and consumption. Lesser increases for coal production may be expected in the Mid-Atlantic, South Atlantic-Gulf, Tennessee, Upper Mississippi, Upper Colorado, and Lower Colorado Regions. Water requirements for coal production in the eastern regions could increase greatly with a combination scenario of an expanded policy of energy self-sufficiency and/or technical developments to utilize the high sulfur coals. The western coal regions will face critical water problems with expanding coal production (subject to environmental constraints), especially if the coal is used for conversion to electricity in the region and if there is an oil shale/sands technology breakthrough for extracting these fuels.

Metals Mining

The metals mining industry uses the least water of the three mineral categories--about 11 and 13 percent of all withdrawals and consumption respectively (Table III-54). However, consumption of water for metals mining is about 36 percent of the amount withdrawn compared to 15 percent for non-metals and about 54 percent for fuels. Water uses for metals mining are largely for washing and primary ore processing of iron, copper, silver, and related metals. Three regions currently

Table III-54
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN METALS MINING INDUSTRIES BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	3	3	4	1	1	1
Mid-Atlantic	14	15	16	2	2	2
South Atlantic-Gulf	5	7	8	1	1	1
Great Lakes	231	250	289	85	91	101
Ohio	2	2	3	1	1	1
Tennessee	8	14	21	1	3	4
Upper Mississippi	45	50	58	7	7	8
Lower Mississippi	14	12	11	3	3	3
Souris-Red-Rainy	0	0	0	0	0	0
Missouri	34	42	45	5	5	7
Arkansas-White-Red	54	70	97	7	10	15
Texas-Gulf	20	33	40	3	4	5
Rio Grande	9	24	44	3	10	19
Upper Colorado	19	30	57	3	6	13
Lower Colorado	150	206	250	138	194	231
Great Basin	122	169	214	25	37	52
Pacific Northwest	58	62	70	8	8	9
California	6	6	7	1	1	2
Alaska	15	54	127	1	21	42
Hawaii	0	0	0	0	0	0
Caribbean	0	0	0	0	0	0
Total, Regions 1-18	802	999	1234	293	382	471
Total, Regions 1-21	817	1053	1361	294	403	513

withdraw more than 100 million gallons of water per day for metals mining--the Great Lakes, Lower Colorado, and Great Basin. No significant changes are expected for the 1985 and 2000 projections.

The Great Lakes Region is the largest using region in this category for iron ore production in Minnesota and Michigan. The second and third largest water uses for metals mining are the Arizona copper mines and the Utah, Nevada, and Idaho silver mines. The Great Lakes Region has one-third of its mineral withdrawals used in metals mining. However, the drier Lower Colorado and Great Basin Regions use 83 percent of the waters for minerals in metals production. More than 92 percent of the water withdrawn is used consumptively in metals mining in the Lower Colorado Region. More than one-half of the minerals water use in Alaska are for metals mining. This will decline to about one-fourth by 2000 since growth in metals mining is projected to be only 8 times the 1975 level (versus 28 times for fuels processing).

Overall growth in water requirements for metals mining will be only about 67 percent from 1975 to 2000. Continued competitive foreign supplies of iron and stabilized production in the Great Lakes should dampen growth of water needs for mining in that region, unless copper resources in Wisconsin and Minnesota are rapidly developed. Basically anticipated efficiencies and conservation in water uses by the metals mining industries will likely be offset by the need to mine and process lower grade ores.

Minerals Water Requirements -- Regional and National

Endowments of minerals in quantities and qualities vary by region and water demands vary accordingly. The largest water using region for mining is the South Atlantic-Gulf Region, largely for nonmetals (construction materials, clays, and phosphates). The second and third largest water using regions for mining are the Texas-Gulf and Lower Mississippi Regions where fuel production is the dominant water use. The fourth largest regional user of mining water is the Great Lakes where the uses are largely for metals mining. The most critical water using regions for mining are the western regions; the Great Basin, Upper and Lower Colorado, portions of the Pacific Northwest, Arkansas-White-Red, and Rio Grande Regions where minerals are abundant and water supplies are short. These areas will be critically short of mining waters as economic factors such as base metal prices; energy self-sufficiency; and environmental requirements increase water needs for low sulfur coal, oil shale, and uranium.

Nationally, mineral production is expected to increase in all categories with an attendent increase in water needs (Table III-55). Regional uses of water in the metals and nonmetals mining will not shift geographically as in the case of fuels production (from the Ohio to the Missouri), but both withdrawals and consumption will increase about 1.6 times between 1975 and 2000. No insurmountable water supply problems

TABLE III-55
SUMMARY OF FRESHWATER WITHDRAWALS AND CONSUMPTION IN MINERALS INDUSTRIES BY WATER RESOURCES REGIONS - 1975, 1985, 2000; AVERAGE YEAR
(MILLION GALLONS PER DAY)

Region	Withdrawals			Consumption		
	1975	1985	2000	1975	1985	2000
New England	90	115	153	11	16	20
Mid-Atlantic	459	548	700	70	82	102
South Atlantic-Gulf	1178	1538	2077	214	274	349
Great Lakes	696	831	1044	155	175	211
Ohio	493	662	808	91	132	160
Tennessee	110	140	186	15	21	27
Upper Mississippi	333	417	533	46	58	74
Lower Mississippi	799	1010	1318	206	253	416
Souris-Red-Rainy	8	9	10	3	3	3
Missouri	269	356	424	111	139	163
Arkansas-White-Red	448	469	571	173	184	218
Texas-Gulf	1044	1133	1245	555	588	632
Rio Grande	190	221	255	103	129	150
Upper Colorado	132	195	355	47	72	144
Lower Colorado	184	252	311	151	217	280
Great Basin	145	206	273	28	44	64
Pacific Northwest	118	141	167	18	19	27
California	297	359	375	183	225	213
Alaska	30	192	476	12	141	350
Hawaii	1	1	1	0	0	0
Caribbean	31	37	46	4	5	6
Total, Regions 1-18	6993	8602	10805	2180	2631	3253
Total, Regions 1-21	7055	8832	11328	2196	2777	3609

are foreseen in the mineral industry, except for some local areas in the western regions, especially Missouri, Great Basin, and Upper and Lower Colorado. Much of the water requirement increases in the petroleum industry will be for increased secondary recovery through water flooding procedures, but no severe water shortage is foreseen in the petroleum production regions.

However, greater competition for scarce water, the need for water to develop energy resources, the increasing cost of its use, and the environmental requirements that come with such uses will require increased efforts by the mineral industries to conserve water. Water requirements will shift within the industry as supply/demand relationships shift bringing about substitution of one material for another and greater incentives for more mineral recycling. A shift to energy production through greater use of coal by methods that meet clean-air requirements will require more water for coal preparation transportation and conversion. Low-sulfur western coal transported to the Midwest through slurry pipelines would effectively displace water from water deficient areas to water sufficient areas.

PART III

CHAPTER 8

WATER REQUIREMENTS FOR RECREATION AND RELATED RESOURCE CONSIDERATIONS

Outdoor activities Americans choose are heavily dependent on and enhanced by both the extent and variety of waters available for recreation. About one-fourth of all outdoor recreation is dependent on water. Outdoor recreation is a complex mixture of types, kinds, intensities, and durations of participation. The Second Asssessment is concerned largely with two types of water-related outdoor recreation-water-dependent (swimming, canoeing, boating, sailing, water skiing, ice skating, and fishing) and water-enhanced (picnicing and camping).

Water-related outdoor recreation participation requires a substantial supply of accessible water and supporting lands and facilities to accommodate the existing 2 billion activity occasions and the 34 percent growth to 2.7 billion occasions projected for 2000. Measurements of recreation requirements and supplies can be made in terms of activity days or activity occasions; surface areas or miles of water or shoreline; acres of land associated with such water areas and the numbers of auxilliary facilities provided. The Second Assessment considered selected criteria--activity occasions, water surface area, miles of stream, and developed land area as the most useful and consistent measures of requirements and supplies of water-related outdoor recreation. An activity occasion refers to an individual participation by a person 12 years of age or older in a water-related recreation activity without regard to the duration or intensity.

There are about 20.3 million acres of surface water accessible and usable for recreation in the conterminous United States (Regions 1-18) or about 122 acres per 1,000 people. However, this recreational surface area is only about one-fourth of the nearly 84.6 million acres of surface water area in the conterminous United States. The remaining 64 million acres of potential recreation water area is now inaccessible, polluted or otherwise restricted from recreational uses. Some of these waters can be added to the available supply with improvements in accessibility and water quality. Estimated and projected additonal needs for water area for recreation are about 8 million acres in 1975, 9.8 million in 1985, and 12.8 million in 2000 to meet acceptable standards of density for the expected participation rates. These additonal needs in 1975 would be for about 48 additional acres per 1,000 population nationally.

However, recreation needs vary considerably from region to region with 5 of the regions having recreational waters in excess of outdoor recreation activity needs. Three of the regions need a doubling of existing area to meet the needs internal to the region. These needs must be balanced against the competitive needs for other instream uses and for withdrawals for other purposes. Many of the Nation's waters usable for recreation are also areas of critical concern for ecological and natural area values. In many areas the successful use of these waters for recreation will depend on the quality of the waters, success in providing timely accessibility, and managing the recreational uses in a manner which maintains the quality of the recreational experiences.

Supply of Water Related Recreation Resources

Recreation surface water is that part of the Nation's waters reasonably available to the public and of suitable quality and accessibility for recreational activities. Assessment data were developed by aggregated subregion and region for total supplies of surface water and recreation surface water (Table III-56). There are about 85 million acres of total surface water in the conterminous states (about 506 acres per 1,000 people), but only 20 million acres or 24 percent is considered useable for recreation. The availability of surface water useable for recreation varies from a low of about 10 percent of the total surface water in the Great Lakes Region (exclusive of the lakes themselves) to a high of 86 percent in the Great Basin Region. The Great Lakes, Lower Mississippi, Texas-Gulf, and Rio Grande Regions have relatively low proportions of total surface waters available for recreation. Conversely, the Ohio, Tennessee, Missouri, Upper Colorado, Great Basin, and California Regions are able to utilize large proportions of total surface waters for recreation.

There are several reasons for such a low percentage of surface water being available for recreation in some regions. Size of the water bodies alone precludes much of the Great Lakes and some coastal waters from recreational uses. This limitation is intensified by lack of adequate harbors, launching facilities, other supporting facilities, and

Table III-56

PARTICIPATING POPULATION, TOTAL SUPPLY OF SURFACE WATER, AND SURFACE WATER USABLE FOR OUTDOOR RECREATION BY WATER RESOURCES REGIONS, 1975

Region	Participating Population a/	Total Surface Water Area		Surface Water Useable For Recreation		
		Acres b/	Acres per 1,000 Population	Acres c/	Percent of Total	Acres Per 1,000 Population
	(Million)	(Million)		(Million)		
New England	9.768	4.103	420	1.480	36	151
Mid-Atlantic	30.993	4.366	140	1.840	41	58
South Atlantic-Gulf	19.984	8.672	433	2.029	23	101
Great Lakes	23.765	41.547	1748	4.253	10	178
Ohio	16.595	.932	56	.519	56	31
Tennessee	2.802	.660	235	.525	80	187
Upper Mississippi	10.469	2.716	259	.753	28	71
Lower Mississippi	5.045	3.433	680	.420	12	83
Souris-Red-Rainy	.508	1.232	2425	.333	27	656
Missouri	6.951	3.504	504	2.494	71	358
Arkansas-White-Red	5.381	1.855	344	.634	34	117
Texas-Gulf	7.791	2.692	345	.387	14	49
Rio Grande	1.346	.542	402	.070	13	52
Upper Colorado	.275	.558	2029	.329	59	1196
Lower Colorado	1.927	.456	236	.209	46	108
Great Basin	1.010	1.752	1734	1.513	86	1498
Pacific Northwest	5.355	3.893	726	1.483	38	276
California	16.906	1.674	99	1.091	65	64
Alaska	.245	12.787	52192	1.937	15	7906
Hawaii	.629	-	N/A	N/A	N/A	N/A
Caribbean	N/A	N/A	N/A	N/A	N/A	N/A
Total Regions 1-18	166.871	84.557	506	20.326	24	122
Total Regions 1-21						

a/ Estimated 1975 population 12 years and older of about 167 million.

b/ Total of inland and other water from Area Measurement Reports, U.S. Department of Commerce Publication GE-20, No. 1 and 1970 update sheet and comprehensive water basin studies.

c/ Water available and useful for recreation. To be available and useful the water must have adequate public access, be free of obstruction to its use, and be of suitable quality for recreation use.

Source: 1972 Nationwide Outdoor Recreation Plan, statewide comprehensive outdoor recreation plans, comprehensive water basin studies, and Technical Memoranda Number 2, 1975 National Water Assessment--Regional Sponsors.

often unfavorable weather conditions. Deterioration of water quality in urban and rural areas has resulted in large portions of the Nation's streams and lakes being unusable for certain types of recreation. Sedimentation, shoreline development, eutrophication, and limited access often limit the Nation's inland lakes and reservoirs for recreational pursuits. Related problems, especially in the South, are reductions in the utility of waterways by aquatic vegetation, parasites, and other disease vectors that limit uses. In some areas with limited surface waters the full range of recreational activities is limited by competing non-complementary uses. Altogether, these conditions have a significant impact on the amount of water available for recreation.

Perhaps the more useful measure of total surface water and recreation surface water supplies is the availability relative to population resident in the region (Table III-56). The supply of recreation surface water acreage per capita is particularly abundant in the Souris-Red-Rainy, Missouri, Upper Colorado, and Great Basin Regions. Surface water areas useable for recreation are also abundant per capita in the Great Lakes, Tennessee, and Pacific Northwest Regions.

Surface water acreages useable for recreation are particularly limited in the Ohio, Texas-Gulf, Rio Grande, and Mid-Atlantic Regions, ranging from 31 to 58 acres per thousand people over 12 years of age. Serious pressures on recreational water supplies exist in the Upper and Lower Mississippi and California Regions. In the conterminous United States (Regions 1-18) the average water area available for recreation is 122 acres per thousand of participating age people (12 years and older). The most critical conditions of recreational water supply occur when the waters are both heavily utilized and few acres are available per capita, such as in California. Those conditions of low availability of total waters and already high density uses, i.e., the Upper and Lower Mississippi, Texas-Gulf, and Rio Grande Regions, are solvable problems when the recreational uses are limited largely by water quality and accessibility constraints. Concerted action to develop additional surface water acreage or to make existing surface water resources available for public use would have a significant impact on recreation needs in these regions. Improved public access to large water bodies can open many areas and opportunities to the public for water related recreation.

An increasingly important aspect of water related recreation is the use of rivers and streams. Although no evaluation of streams for recreation was explicitly made in this Assessment some indications of availability of streams for recreation can be gained from the water quality evaluations (Table III-57). In the conterminous states there are about 260 thousand miles of streams of which 29 percent is of limited use due to low quality conditions.

Measurements are not available for other constraints such as low flows which are generally more limiting to streams than to lakes and reservoirs. If adjustments are made for quality limitations one finds that 30 percent of the remaining stream mileage of suitable quality is required to meet 1975 recreational demands without regard to other

Table III-57

SUMMARY OF STREAM MILES AND PROJECTED STREAM MILE REQUIREMENTS FOR WATER-DEPENDENT OUTDOOR RECREATION BY WATER RESOURCES REGIONS - 1975, 1985, 2000

Region	Stream Miles Available 1975	Streams Not Meeting Quality Standards 1975	Stream Miles Requirements for Recreation (miles)		
			1975	1985	2000
	(miles)	(percent)			
New England	29734	13	2711	3030	3650
Mid-Atlantic	16418	23	8570	10610	12360
South Atlantic-Gulf	27538	32	7000	8330	10510
Great Lakes	12229	16	9260	10280	12090
Ohio	28992	39	4770	5320	6160
Tennessee	2337	8	980	1140	1400
Upper Mississippi	9370	32	4060	4560	5370
Lower Mississippi	14132	50	1770	1920	2170
Souris-Red-Rainy	850	5	300	300	300
Missouri	8399	6	4808	5105	5714
Arkansas-White-Red	34897	55	2130	2290	2630
Texas-Gulf	12388	9	2730	3170	3910
Rio Grande	4350	8	413	453	495
Upper Colorado	7068	5	194	220	232
Lower Colorado	2875	5	560	680	914
Great Basin	5595	31	286	354	442
Pacific Northwest	30532	40	1542	1683	1914
California	12639	5	2975	3408	4126
Alaska	N/A	N/A	70	85	110
Hawaii	N/A	N/A	180	220	270
Caribbean	N/A	N/A			
Total, Regions 1-18	260343	29	55059	62853	74387
Total, Regions 1-21	N/A	N/A			

constraints. However, in some regions such as the Middle-Atlantic, Great Lakes, Upper Mississippi, and Missouri more than 60 percent of the suitable quality stream miles are necessary to satisfy 1975 demands in accord with prevailing acceptable participation densities. As with surface water supplies, stream water supplies are highly variable within regions with about half of the 106 aggregated subregions subject to limited availability of recreational waters.

Participation in Water-Related Recreation

The frequency, duration, and type of participation in water related recreation involves a number of complex economic, social, and personal preference variables. The Outdoor Recreation Resources Review Commission considered leisure time, income, and mobility as major recreation demand variables. More recent studies indicate that discretionary income, leisure lifestyle, supply of outdoor recreation opportunity, and the sequence of leisure time may be more important in estimating participation and projecting changes in demand for recreation. These personal factors, along with increased population, longer life expectancy, population shifts from rural to urban areas, and migration of people to sunbelt areas influence present and future recreation participation patterns.

Participation activity occasions for water-dependent activities of beach swimming, boating, canoeing, fishing, sailing, and water skiing were estimated to be 1359 million occasions (about 550 million recreation days) in 1975 for the conterminous states. Water-enhanced recreation activity occasions (picnicing and camping) were 656 million (about 330 million recreation days) in 1975 (Tables III-58 and III-59). The total water-related activity occasions were over 2 billion, about 67 percent water dependent and 33 percent water-enhanced. Data for Alaska, Hawaii, and Caribbean Regions are incomplete. The water-dependent activity occasions are heavily weighted by beach swimming (43 percent), fishing (28 percent), and boating (20 percent). The remaining 9 percent of water-dependent occasions consist of water skiing, sailing, and canoeing. Swimming, boating, and water skiing are relatively more popular in the western regions while fishing, canoeing, boating, and sailing are more frequent activities in the eastern regions (Table III-58). Camping and picnicing activities are more frequent participations relative to direct, water-dependent activities in the western regions than in the eastern regions with the South Atlantic-Gulf and Tennessee Regions being particularly oriented to water-dependent activities.

Water-Related Recreation Needs

Water-dependent and water-enhanced recreation needs were measured for the Assessment in terms of both activity occasions (summer months June, July, and August only) and water resources required. Resource requirements were projected for participating age population (12 years and older) in each aggregated subregion with aggregations for each region to develop a requirements estimate for acres of surface water, miles of stream, and acres of developed land for water related activities for 1975, 1985, and 2000.

Table III-58
SUMMARY OF WATER-DEPENDENT OUTDOOR RECREATION ACTIVITY OCCASIONS BY WATER RESOURCES REGIONS, 1975

Region	Swimming		Canoeing		Boating		Skiing		Sailing		Fishing		Total Water-Dependent	Total Water-Ehanced	Total Water-Related
	Million	Per-cent	Million	Per-cent	Million	Per-cent	Million	Per-cent	Million	Per-cent	Million	Per-cent	(Million)		
New England	30.4	44	1.7	3	14.2	20	3.1	5	2.6	4	17.8	26	69.7	35.7	105.4
Mid-Atlantic	93.4	43	5.5	3	44.6	20	10.1	5	8.1	4	56.3	26	217.9	115.0	333.0
South Atlantic-Gulf	67.9	42	2.2	1	26.8	17	8.0	5	2.6	2	53.0	33	160.5	57.9	218.4
Great Lakes	89.9	41	4.5	2	50.1	23	12.8	6	3.5	2	59.6	27	220.4	106.6	326.9
Ohio	59.8	42	2.4	2	27.4	19	7.5	5	2.4	2	42.6	30	142.1	58.9	201.0
Tennessee	9.5	42	0.3	1	3.8	17	1.1	5	0.4	2	7.4	33	22.5	8.0	30.5
Upper Mississippi	38.5	40	2.0	2	22.6	23	5.8	6	1.5	2	26.9	28	97.3	47.6	145.0
Lower Mississippi	17.1	42	0.6	1	6.8	17	2.0	5	0.7	2	13.4	33	40.7	14.5	55.2
Souris-Red-Rainy	1.9	40	0.1	2	1.1	23	0.3	6	0.1	2	1.3	28	4.7	2.3	7.0
Missouri	25.9	42	1.1	2	13.6	22	3.8	6	1.0	2	16.4	27	61.9	32.8	94.7
Arkansas-White-Red	18.7	42	0.7	2	8.1	18	2.4	5	0.7	2	13.9	31	44.5	18.0	62.5
Texas-Gulf	26.5	42	0.9	1	10.4	17	3.1	5	1.0	2	20.7	33	62.6	22.3	84.9
Rio Grande	5.0	46	0.1	1	1.9	18	0.7	6	0.2	2	2.9	27	10.7	5.9	16.6
Upper Colorado	1.1	48	<.1	1	0.4	19	0.1	7	<.1	2	0.5	24	2.2	1.4	3.6
Lower Colorado	7.4	48	0.2	1	2.8	19	1.0	7	0.3	2	3.6	24	15.4	9.8	25.2
Great Basin	3.9	48	0.1	1	1.5	19	0.5	7	0.2	2	1.9	24	8.0	5.2	13.2
Pacific Northwest	20.5	48	0.5	1	7.9	19	2.9	7	0.9	2	10.1	24	42.7	27.4	70.1
California	64.7	48	1.6	1	24.9	19	9.0	7	2.8	2	31.8	24	134.8	86.4	221.2
Alaska	0.9	48	<.1	1	0.4	19	0.1	7	<.1	2	0.5	24	2.0	1.3	3.2
Hawaii	3.9	21	0.1	3	0.9	5	0.3	2	0.1	1	1.2	7	18.2	5.9	24.1
Caribbean	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	0.8	N/A
Total, Regions 1-18	582.0	43	24.4	2	269.0	20	74.4	5	28.9	2	379.9	28	1358.7	655.7	2014.4
Total, Regions 1-21													1378.9	663.7	2042.6

Note: Activity occasions were obtained by multiplying estimated regional summer recreation participation rates by OBERS "Series E" population projections. Adjustments were made to obtain estimates of the population 12 years and older, a frequently used statistic in recreation estimates. These data were obtained by multiplying OBERS "Series E" figures by the percent of the actual 1970 population 12 years and older in each subregion. Summer participation rates were derived from the Bureau of Outdoor Recreation's publication "The 1965 Survey of Outdoor Recreation Activities." All data in this assessment are referenced to these summer participation rates (Tables 9A, 9B) as the critical period for meeting demands.

Table III-59

SUMMARY OF PARTICIPATION FACTORS AND STANDARDS FOR SELECTED WATER-DEPENDENT AND WATER-RELATED OUTDOOR RECREATION REQUIREMENTS

	Average Hours Per Activity Day	Units	Daily Intensity of Use		
			High	Medium	Low
Water Related					
Beach Swimming	2.61	Visitors Per Acre	1250	720	300
Lake Fishing	4.44	Visitors Per Acre	1	0.5	0.2
Stream Fishing	4.44	Visitors Per Mile	2	1	0.4
Boating	2.84	Visitors Per Acre	2	1	0.5
Water Skiing	2.62	Visitors Per Acre	0.25	0.125	0.67
Ice Skating	2.62	Visitors Per Acre	2600	1300	650
Water Enhanced					
Camping	24.00	Visitors Per Acre	40	24	12
Picnicking	2.73	Visitors Per Acre	90	60	30

Both water-dependent and water-enhanced activity occasions are projected to grow by 34 percent, from 2 billion occasions to 2.76 billion over the 25 years 1975-2000 (Table III-60). Growth among regions will vary from none in the Souris-Red-Rainy Region to 65 percent in the Lower Colorado. Other regions of slow growth in water-related recreation needs include the Lower Mississippi, Missouri, Arkansas-White-Red, Rio Grande, and Upper Colorado Regions. Rapid growth is projected for the South Atlantic-Gulf, Texas-Gulf, Great Basin, California, Alaska, and Hawaii Regions. These growth projections may be understated because of the trends in migration (as well as tourist activity) to southern regions in which water-dependent recreation, especially such a major component as fishing, is spread over a season much longer than the three summer months presented here.

Surface water requirements for 1975 are rather closely related to population (Table III-61). Surface area useable for water-dependent recreation totaled more than 15 million acres or above 122 acres per thousand of participating age population in 1975. This analysis for the Assessment was made by aggregated subregion with an assumption of independence of participation among regions, i.e., each region's population was assumed to participate only within the aggregated subregion when supply and demand comparisons were made. The aggregated subregion projections of surplus or deficit water surface area were algebraically summed for the regions for a projection of net surplus or deficit for each region, again without consideration of regional interactions (Table III-61).

Table III-60
SUMMARY OF WATER-DEPENDENT AND WATER-RELATED OUTDOOR RECREATION REQUIREMENTS BY WATER RESOURCES REGIONS - 1975, 1985, 2000

	Water Dependent			Water Enhanced		
Region	1975	1985	2000	1975	1985	2000
		(Million Occasions)			(Million Ocassions)	
New England	69.8	77.9	91.0	35.7	40.9	48.4
Mid-Atlantic	217.9	246.6	289.3	115.0	131.0	155.9
South Atlantic-Gulf	160.5	192.0	235.1	57.9	68.4	85.3
Great Lakes	220.4	247.1	295.0	106.6	119.1	138.7
Ohio	142.1	158.3	182.8	58.9	65.5	75.5
Tennessee	22.5	26.4	31.9	8.0	9.4	11.3
Upper Mississippi	97.3	112.0	126.4	47.6	53.0	61.4
Lower Mississippi	40.7	44.3	49.4	14.5	15.8	17.6
Souris-Red-Rainy	4.7	4.7	4.8	2.3	2.3	2.3
Missouri	61.9	67.5	77.2	32.8	35.7	40.8
Arkansas-White-Red	44.5	48.6	55.8	18.0	19.7	22.2
Texas Gulf	62.6	73.1	89.2	22.3	26.0	31.7
Rio Grande	10.7	11.7	13.1	5.9	6.5	7.3
Upper Colorado	2.2	2.3	2.6	1.4	1.5	1.7
Lower Colorado	15.4	19.2	25.4	9.8	12.3	16.3
Great Basins	8.0	9.7	12.2	5.2	6.2	7.8
Pacific Northwest	42.7	46.1	53.1	27.4	29.6	34.0
California	134.8	156.6	189.5	86.4	100.4	121.3
Alaska	2.0	2.4	3.1	1.3	1.5	2.0
Hawaii	18.2	20.8	25.6	5.9	6.6	8.0
Caribbean	N/A	0.9	1.2	0.8	0.9	1.1
Total, Regions 1-18	1358.7	1544.0	1823.7	655.7	743.3	879.4
Total, Regions 1-21	1378.9	1568.1	1853.6	663.7	752.3	890.5

Table III-61
ESTIMATED AND PROJECTED NEEDS FOR SURFACE WATER AREA
FOR WATER-DEPENDENT OUTDOOR RECREATION ACTIVITIES
BY WATER RESOURCES REGIONS - 1975, 1985, 2000 a/ b/

Region	Available Acres Total	Available Acres 1975 f/ Per 1,000 Population	1975 Gross Surplus Water Acres c/	1975 Gross Deficit Water Acres d/	1975 Net Regional Surplus or (Deficit) Acres e/	1985 Gross Surplus Water Acres c/	1985 Gross Deficit Water Acres d/	1985 Net Regional Surplus or (Deficit) Acres e/	2000 Gross Surplus Water Acres e/	2000 Gross Deficit Water Acres d/	2000 Net Regional Surplus or (Deficit) Acres e/
	(1,000)	f/	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)	(1,000)
New England	1138	117	902	560	342	879	681	198	833	929	(96)
Mid-Atlantic	2813	91	670	1679	(1009)	612	2106	(1494)	512	2702	(2190)
South Atlantic-Gulf	2380	119	607	958	(351)	446	1208	(762)	236	1665	(1429)
Great Lakes	2637	111	2900	1284	1616	2816	1504	1312	2676	1888	788
Ohio	1480	89	0	961	(961)	0	1129	(1129)	0	1404	(1404)
Tennessee	333	119	192	0	192	140	0	140	111	45	66
Upper Mississippi	1178	113	84	509	(425)	29	585	(556)	2	783	(781)
Lower Mississippi	599	119	3	182	(179)	0	226	(226)	0	292	(292)
Souris-Red-Rainy	122	240	211	0	211	212	0	212	210	0	210
Missouri	524	75	1976	6	1970	1939	10	1929	1880	22	1858
Arkansas-White-Red	705	131	179	250	(71)	174	300	(126)	163	382	(219)
Texas-Gulf	926	119	0	539	(539)	0	678	(678)	0	901	(901)
Rio Grande	187	139	12	129	(117)	11	142	(131)	10	160	(150)
Upper Colorado	19	69	310	0	310	310	0	310	307	0	(307)
Lower Colorado	201	104	102	94	8	81	128	(47)	68	185	(117)
Great Basin	154	152	1360	1	1359	1334	2	1332	1295	5	1290
Pacific Northwest	763	142	818	98	720	807	138	669	791	232	559
California	1422	84	475	806	(331)	454	977	(523)	419	1244	(825)
Alaska	36	147	1901 N/A	0 N/A	1901 N/A	1896 N/A	0 N/A	1896 N/A	1882 N/A	0 N/A	1882 N/A
Hawaii	N/A	N/A									
Caribbean	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A
Total, Regions 1-18	20326	122	10801	8056	2745	10244	9814	430	9513	12839	(3326)
Total, Regions 1-21	-	-	-	-	-	-	-	-	-	-	-

a/ Water available and useful for recreation. The need may be met through provision of adequate public access, removal of obstructions to use, improvement of water quality or additional water area.

b/ Activities include boating, sailing and water skiing. Analysis for these three activities also provides for adequate consideration of fishing, which involves considerable overlapping use of the same resources and for canoeing and swimming, since these activities require a relatively insignificant water acreage.

c/ Total for a water resource region is the total of those ASRs with surplus water acreage relative to needs within each ASR.

d/ Total for a water resource region is the total of those ASRs with deficit water acreage relative to needs within each ASR.

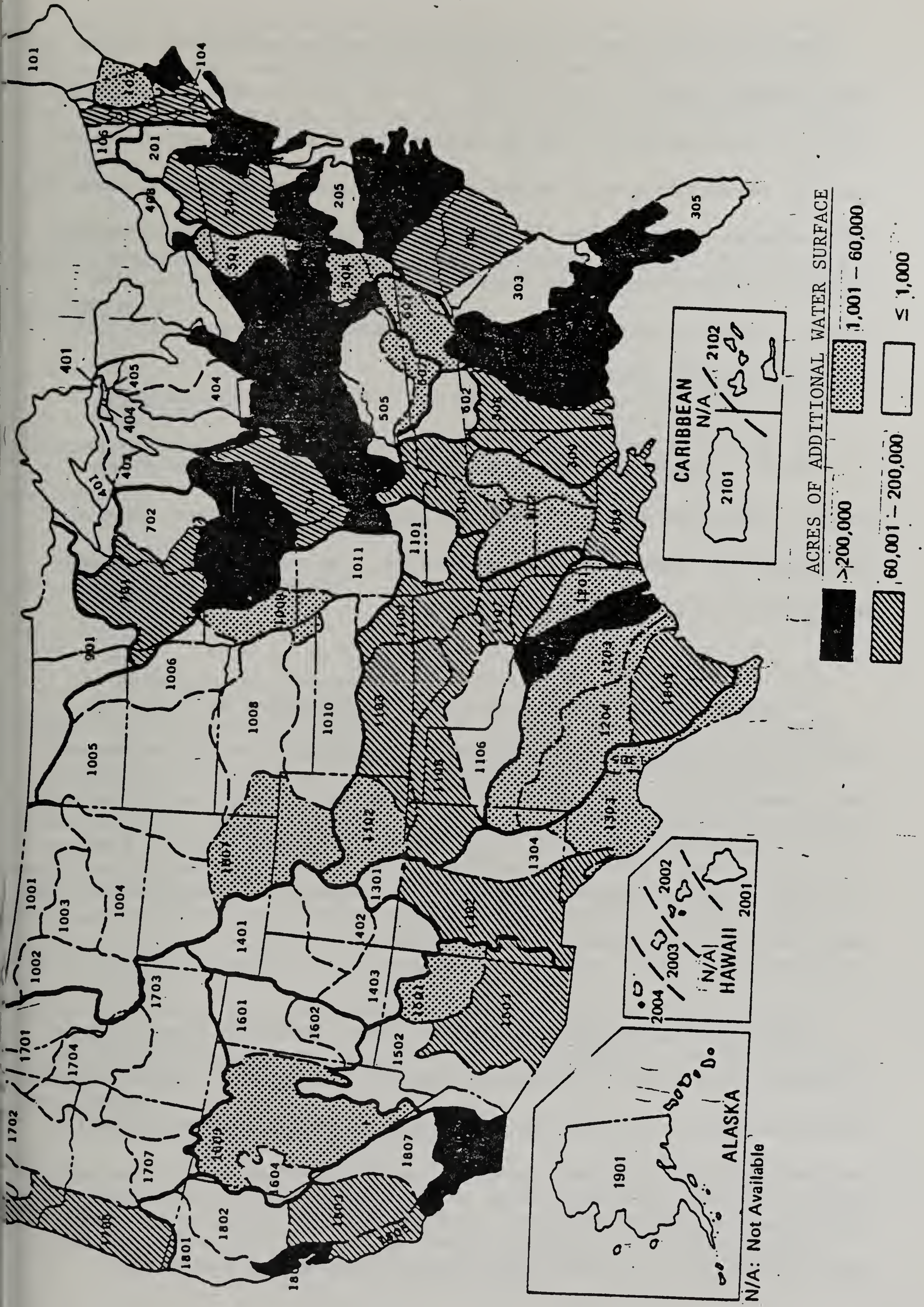
e/ The algebraic difference between surplus and deficit ASAs i.e. a regional composite view of net needs for the region.

f/ Based on estimated 1975 population 12 years and older and projected 1985 and 2000 population 12 years and older.

Source: Nationwide Analysis Outdoor Recreation, Bureau of Outdoor Recreation, May 1975 and Technical Memoranda Number 2, 1975 National Water Assessment--Regional Sponsors.

The gross surplus in 1975 of 10.8 million acres of surface water useable for recreation in the U.S. (Regions 1-18) was offset (by Regions) with deficit waters for the population of 8.1 million acres for a net supply of 2.7 million acres of water relative to total available useable recreation area of 20.3 million acres. In 1975, 52 of the 106 aggregated subregions had needs for additional recreation surface water. The largest need existed in the area which includes New York City. It had a deficit of over 1 million acres of recreation surface water and only a small portion of that need could be met through better access or improved water quality. Regions with needs of over 350,000 acres of recreation surface water are Great Lakes, New England, California, and Texas-Gulf Regions which include the Chicago, Boston, Los Angeles, and Dallas-Fort Worth metropolitan areas, respectively. Virtually all of these urban centers are adjacent to major surface water resources where quality or access are limited, the water body is too large to be effectively utilized, or a significant number of citizens lack mobility (Figure III-22).

On a regional basis the Ohio, South Atlantic-Gulf, Mid-Atlantic and Lower Mississippi, Texas-Gulf, Rio Grande, Arkansas-White-Red, and California Regions have net deficit supplies of surface water area in 1975. The other regions may include subregions with deficits, but the whole region could satisfy its recreational demands for surface water. Several regions, the Great Lakes, Missouri, Great Basin, Pacific Northwest, and Alaska have a substantial surplus of surface water acres relative to projected demands (Table III-61).


ACRES OF ADDITIONAL WATER SURFACE
■ >200,000
▨ 60,001 - 200,000
▒ 1,001 - 60,000
☐ ≤ 1,000
CARIBBEAN
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ALASKA
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N/A
HAWAII
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2002
2003
2004
N/A: Not Available
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Figure III-22

ADDITIONAL WATER SURFACE AREA NEEDED FOR
WATER-RELATED OUTDOOR RECREATION BY 2000 BY AGGREGATED SUBREGIONS

The increasing needs for recreational surface waters are evident in the changing number of regions with a net deficit in 2000 (12 regions) versus 1975 (9 regions). The New England and Upper and Lower Colorado Regions' requirements will exceed available supplies of surface water by 2000, whereas these regions now enjoy a surplus for 1975 requirements. Increases in deficits of substantial amounts will occur in the Mid-Atlantic, South Atlantic-Gulf, Upper Mississippi, Arkansas-White-Red, Texas-Gulf, and California Regions.

In the conterminous United States the 2.7 million acres of net surplus recreation waters in 1975 will decline to just better than a breakeven basis between surplus and deficit regions in 1985 and a net deficit of 3.3 million acres in 2000.

The change from a surplus to a deficit of recreation water is usually the result of population growth. A majority of the increased needs identified in this Assessment could be met through more effective use of total surface waters. In all likelihood, many needs will be met by travel to other regions where there is adequate recreation water, but such travel will be costly in terms of time and energy.

Recreation demands for streams are also expected to grow by about 35 percent from 1975 to 2000 (Table III-57). In several regions (especially the Mid-Atlantic, Great Lakes, and Missouri) stream mile requirements for 2000 will press against or exceed usable stream miles for recreation unless substantial improvements in stream water quality, access, and other constraints on recreational uses of streams are instituted.

The developed land area needs for recreation do not present a major problem of resource availability, but planning and construction of such areas to meet requirements must be carefully and adequately done (Figure III-23).

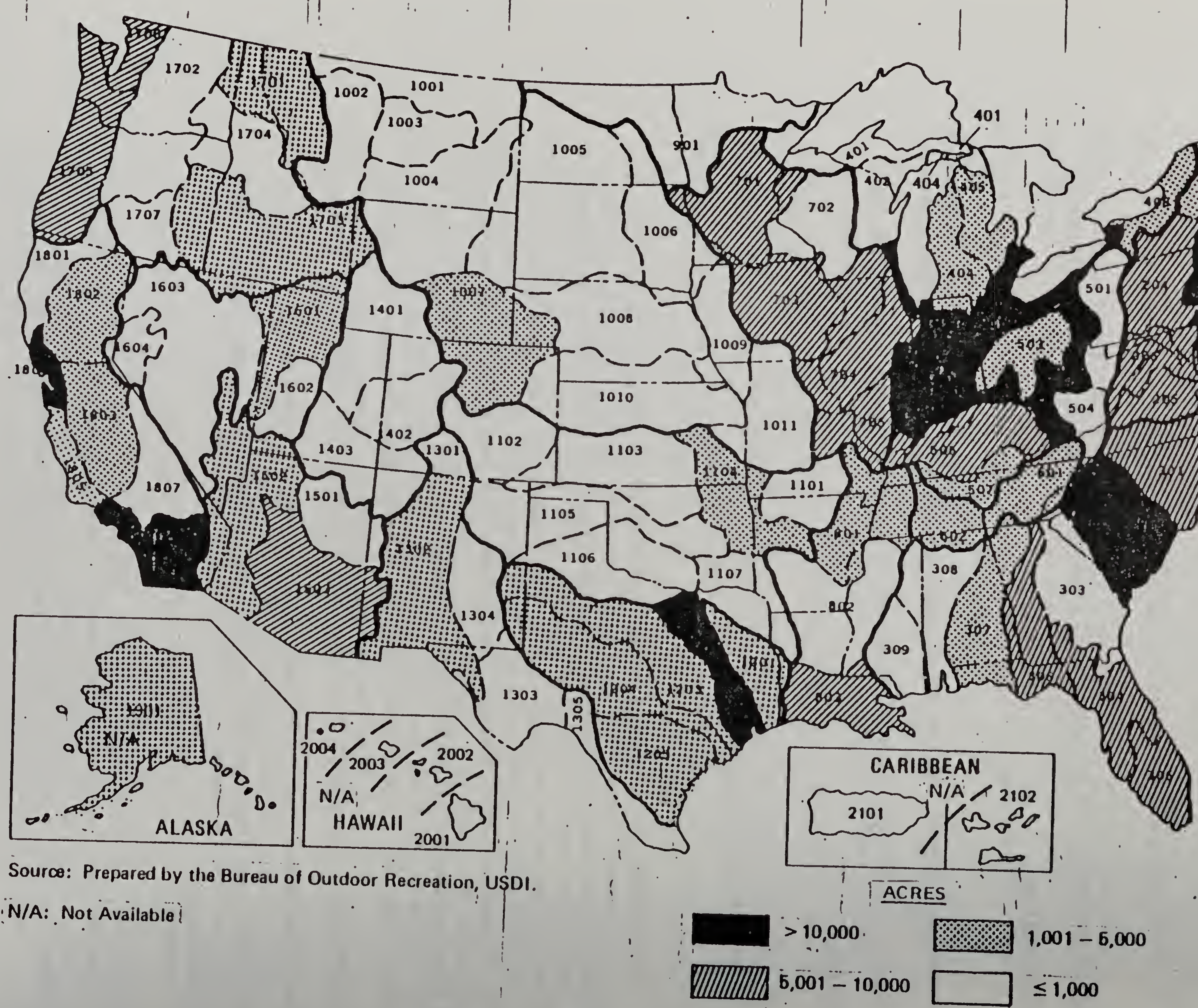
Related Resource and Institutional Considerations in Water Requirements for Recreation

Looking beyond the numerical data in the Assessment, several areas of resource and institutional concern for water-related recreation are important.

Urban Recreation Water Needs

The United States is becoming essentially an urban Nation: 73.5 percent of all Americans lived in urban areas in 1970. One consequence is that choice water related recreation land in or near metropolitan areas is almost always desired for residential and commercial development and thus extremely expensive for recreation uses. There can be little question that most urban areas provide limited water related recreation opportunities, especially for inner-city residents. Many local jurisdications experience great difficulty in putting together major recreation acquisition and development programs and in managing resources for their own residents.

Because people are concentrated in urban areas while water resources are often at some distance transportation problems, including energy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HAWAII
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2002
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2004
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CARIBBEAN
2101
2102
N/A
ACRES
■ > 10,000
▨ 5,001 – 10,000
▒ 1,001 – 5,000
☐ ≤ 1,000

Source: Prepared by the Bureau of Outdoor Recreation, USDI.

N/A: Not Available

Figure III-23

ADDITIONAL LAND AREA NEEDED FOR WATER-RELATED scarcity, add pressure to make recreation opportunities more accessible to urban populations. Virtually every major urban center is located adjacent to major water resources often inaccessible or too polluted to enjoy. As water quality improves in urban areas through implementation of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), the recreational opportunities should increase for a substantial public benefit.

Conflicts with other land uses in urban areas underscore the problem of trying to meet water-related outdoor recreation needs. Recreation demand projections demonstrate the pressing need to plan for additional recreation resources for the Nation's large metropolitan areas either by enhancing existing recreation resources or by establishing new, urban oriented river and lake front areas. This can be partially accomplished through coordination of Section 208 water quality planning (P.L. 92-500) and by implementation of Section 73b of the Water Resource Development Act of 1974 (P.L. 93-251). Both programs offer recreation planners a way to protect and enhance present and future water-related recreation opportunities.

Competing Uses--Energy and Agriculture

Water availability for recreation appears to be on a collision course in competition with energy, industrial, and agricultural development interests. Increasingly important is the competition between these instream and off-stream water uses.

Future energy development is highly dependent upon the availability of water. Water is essential to all phases of energy development from mining to revegetation of mined lands. Management of existing reservoirs for recreation to maintain minumum reservoir pools during the recreation season and for coordinated water releases to enhance or protect downstream river recreation opportunities could be seriously affected by anticipated water requirements for energy development. Demands for water to support coal and other energy development will undoubtedly cause consideration of new reservoirs. Various energy development proposals could also affect important recreation streams and effectively eliminate recreation for many miles below the scene of energy developments.

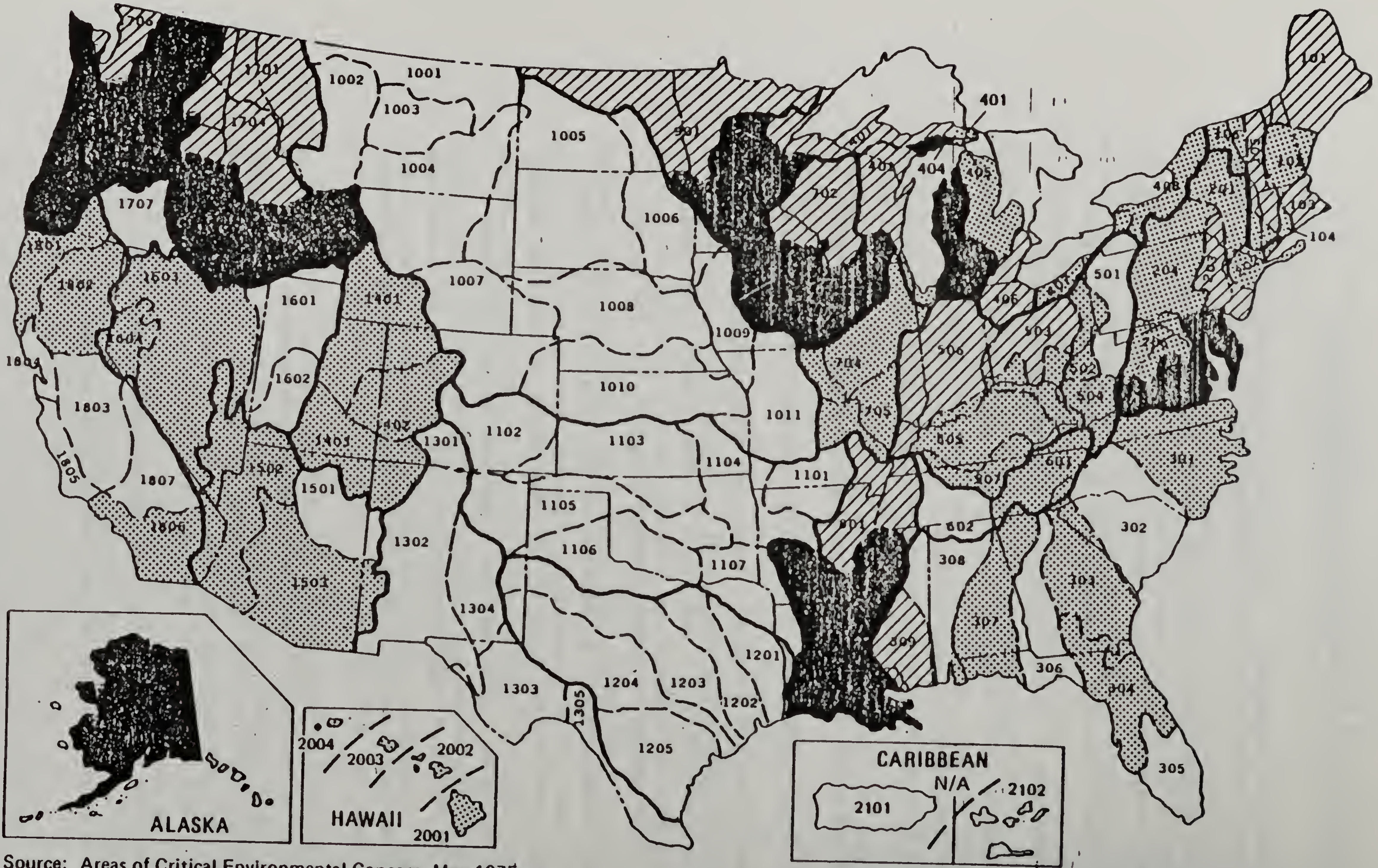
Agricultural development, the second major competitor with recreation for scarce water resources, demands and needs water for irrigation. Past Federal policies toward irrigation development were based on the need to promote settlement and economic development of the West. While these may no longer be primary goals, there is still an effort to develop rural areas of low growth or depressed economies and to promote agricultural growth on the basis of providing water supplies. Agricultural priorities can seriously affect the availability of surface and stream waters for recreation. Both energy development and irrigation will compete with recreation in areas of limited water resources. Each can significantly affect reservoir recreation management and free-flowing stream values. Adequate consideration of recreation values in all development stages will be essential to resolving these potential conflicts.

Environmental Concerns and Recreational Water Requirements

There are many areas of critical environmental concern. Well known and protected are unique water recreation areas such as Grand Canyon, Yellowstone, and Assateague Island. However, many lesser known natural resources also require special consideration for preservation, protection, or enhancement of their significant recreational values. During the Assessment 2,119 areas of significant value for water related recreation were identified (Figure III-24).

All identified areas faced some threat which could cause irreversible damage to the resource. These areas include coastal shoreline and beach, flood plains and wetlands, lakes, streams, islands, unique natural areas such as waterfalls and areas of significant open space or scenic value. The concerns by water resource regions for 998 of the 2,119 areas were summarized for a National total (Table III-62). However, these totals mask differences in the importance of concerns in any one water resource region. The relative magnitude of an individual concern in a water resource region emphasizes the problems of preserving, protecting or enhancing a specific type of critical recreation resource.

The problem of preserving free-flowing stream values was a high priority problem in 73 of the 106 aggregrated subregions. The Assessment and other reports have highlighted numerous examples of modifying natural streams to provide for flood control, navigation, power, and other uses--often without full consideration of the free-flowing values of streams


ALASKA
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Source: Areas of Critical Environmental Concern, May 1975.
Prepared by Bureau of Outdoor Recreation, USDI.

N/A: Not Available

Number of Areas

■ > 40
▨ 26 – 40
▩ 11 – 26
☐ 0 – 10

Figure III-24

Table III-62
CRITICAL ENVIRONMENTAL CONCERNS BY WATER RESOURCES REGIONS, 1975

Water Resource Region	Residential Development	Commercial Development	Industrial Development	Agricultural Development	Mining and Related Resource Development	Dam or Irrigation Project	Navigation Project	Channelization Project	Water Level Fluctuation	Water Pollution	Sedimentation	Erosion	Nuisance Vegetation	Weed Growth	Eutrophication	Adequate Public Access	Adequate Stream Flow	Recreation Overuse
New England	20	3	2	5	1	5	0	0	1	9	1	0	21	10	1	57	4	0
Mid-Atlantic	21	1	5	4	3	4	1	2	0	13	7	1	22	6	26	44	0	0
South Atlantic-Gulf	13	6	0	0	4	13	5	34	3	8	2	1	8	0	0	1	2	0
Great Lakes	73	4	4	2	6	0	0	3	0	41	8	12	0	0	0	12	0	1
Ohio	18	0	0	3	3	5	2	0	0	2	0	1	0	0	2	14	0	0
Tennessee	6	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Upper Mississippi	126	7	5	35	0	5	14	27	2	100	35	15	2	2	6	32	0	5
Lower Mississippi	2	0	0	22	0	0	0	7	1	0	0	1	0	0	2	57	0	0
Souris-Red-Rainy	3	2	0	1	2	9	0	4	0	16	1	0	0	0	0	3	0	0
Missouri	9	2	3	5	9	21	0	6	8	18	8	6	0	1	3	5	12	0
Arkansas-White-Red	2	4	0	5	0	5	0	1	0	2	0	1	2	0	0	1	0	0
Texas-Gulf	17	19	5	7	0	2	1	5	2	13	6	1	0	0	0	3	1	0
Rio Grande	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0
Upper Colorado	1	0	0	0	13	21	0	0	0	8	0	3	0	0	2	0	2	0
Lower Colorado	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Great Basins	4	1	0	0	0	1	0	0	3	2	0	0	0	0	1	6	16	1
Pacific Northwest	5	3	0	1	1	19	1	1	23	31	2	1	0	0	0	20	37	0
California	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0
Alaska	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hawaii	5	9	1	10	0	10	0	0	0	0	0	0	0	0	0	0	0	3
Caribbean	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total, Regions 1-18	320	52	24	90	42	112	24	91	43	266	71	44	55	19	43	255	76	7
Total, Regions 1-21	325	61	25	100	42	122	24	91	43	266	71	44	55	19	43	256	76	11

Source: Nationwide Analysis Outdoor Recreation, Bureau of Outdoor Recreation, May 1975 and Technical Memorandum Number 2, 1975 National Water Assessment - Regional Sponsors.

for recreation on fish and wildlife. There is a well recognized need for these developments to include efforts to enhance stream resources. The national wild and scenic rivers system supported by the Wild and Scenic Rivers Act (P.L. 90-542) now encompasses 1,650 miles of rivers in 19 segments with some 700 miles classified as wild, 460 miles as scenic, and 490 miles as recreational. Twenty-six states have also enacted wild and scenic rivers legislation.

Maintaining stream flows for recreation is a relatively new but significant concept, as water is increasingly allocated among competing uses. A problem in maintaining such flows is most evident in the Upper Colorado, Pacific Northwest, and California Regions. Consumptive demands for water in water-short areas are generally favored over recreation demands because of legal constrains and economic interests.

Water rights in the West have traditionally been tied to beneficial use of water as defined by state law. Beneficial uses generally include municipal and industrial water supplies, stock watering, agriculture, and mining but seldom recreation or aesthetics. Recognition of the necessity for maintaining water in the stream for recreation will be more critical as energy and agricultural developments compete for scarce water resources in many parts of the country.

Many resources require only some form of protection to be available for public enjoyment. Flood plains, coastal beaches, and wetlands in a natural state are examples. They can provide a significant resource base for meeting high priority recreation needs, a means for reducing or liminating flood conditions, and, at the same time, a pleasing contrast o intensive urban development.

Coastal and Great Lakes beaches, some of nature's most vulnerable esources, can erode to the extent that they become unusable for recreation. mproper construction of jetties, breakwaters, and other structures can ggravate the natural process of erosion by interferring with the water nd sand circulation patterns that replenish beaches. Unlimited recreation se cannot be accommodated without environmental damage. Indeed, too many people in such fragile areas can destroy the very features that ttracted the recreationist in the first place.

Urbanizing pressures along coastal and Great Lakes shorelines have generated major environmental and recreational problems. The practice of dredge and fill operations in conjunction with real estate development has been particularly damaging to the environment and continues to destroy resources. Since recreation shorelines are highly desirable for other uses, such as industrial and power development, future pressures in many metropolitan areas will intensify. On the other hand, these shorelines will become increasingly valuable to satisfy recreation demand.

Improving Water Quality For Recreational Uses

Man's activities have degraded water quality to the point that water related recreation opportunities have been diminished or entirely eliminated on some bodies and streams.

Water quality is especially critical in the vicinity of cities where needs are greatest and water resources limited. Many urban areas have developed around harbors or along river transportation arteries, but planners in metropolitan areas have often neglected these potential recreation resources because of water quality problems. Increased outdoor recreation opportunities may be provided in conjunction with the cleanup of waters under the provisions of the Federal Water Pollution Control Act Amendments of 1972, (P.L. 92-500), and more specifically under areawide waste treatment management planning authorized by Section 208 of the Act.

The Section 208 program can integrate solutions to water quality problems involving environmental and developmental considerations and coordinate outdoor recreation programs with efforts to clean up the Nation's waters on the premise that water quality control problems cannot be solved by technology alone. Since water quality is influenced by patterns of land use, dedication of land to parks and recreation uses have been found to contribute greatly to improved water quality.

Managing Reservoirs For Recreational Purposes

Improved utilization of existing water resources is one means of meeting needs with very little alteration of the environment. Many Federal water resource projects built before 1960 did not include provisions for recreation. Consequently, present reservoir operations do not allow for meeting or enhancing recreation needs. The Federal Water Project Recreation Act of 1965 (P.L. 89-72) established recreation as a factor in investigating and planning Federal water resource projects. Inclusion of recreation as a purpose equal to all others in Federal water resource projects allows for acquisition of land for public recreation use, for control of shoreline development, and for modifying reservoir operating procedures in the interest of enhancing recreation use and related environmental values.

Municipal water supply reservoirs offer addtional recreation opportunities. These reservoirs and associated watershed lands are an ideal resource for significant public recreation opportunities, often in close proximity to major population centers. Significant recreational opportunities were identified in New England, Ohio, and South Atlantic-Gulf Regions for using municipal water supply reservoirs.

Historically, recreation use of water supply reservoirs has been restricted to protect public health. Such a policy was both workable and essential in the past when water treatment was not available.

Today, improvements in water treatment technology, either widely used or likely to be required, make possible the safe use of reservoirs and associated watershed lands. Under these conditions recreation becomes not only a compatible use but also a very practical way to insure the public support necessary for continued long-term protection of the watershed from the encroachment of more intensive uses.

Providing Public Access to Recreation Waters

The great diversity of access rights to waters for recreation can confuse and discourage the recreationist. In states where the lands beneath the lake or stream are in private ownership public uses of waters for recreation can be prohibited by the owners of such lands. In many states where public access is a normally guaranteed right it is not always enforced and many shorelines are fenced off or otherwise made inaccessible. The adverse effects of excluding the public from shorelines have resulted in increased pressures on lake, stream, and ocean frontage available to the public.

The importance of public access to surface water cannot be over emphasized. Assessment data indicate that less than 25 percent of total surface water is available and suitable for recreation. A major effort to examine public access policies and programs including, as appropriate: existing legal rights of access, tools and techniques for enforcing hese rights such as acquiring access in residential developments, evelopment of access at bridge and road closures, management options or maintenance and liability questions, establishment of new funding rograms for access purposes, and mandatory programs for providing access in conjunction with new transportation projects. These considerations regarding public access should be evaluated and addressed in appropriate forums to develop incentives and opportunities for more access to the Nation's waters for recreation.

Summary

Several issues face recreation planners trying to provide sufficient water related recreation opportunity for the public. These include: (1) providing urban recreation opportunities; (2) providing maximum recreation opportunities at reservoirs; (3) improving water quality; (4) maintaining stream flows for recreation; (5) retaining flood plains, coastal beaches, and wetlands for recreation; and (6) providing public access to recreation waters.

To plan adequately for the increasing need for outdoor, water related recreation opportunity, greater effort is needed to develop a uniform recreation planning system and a Federal data collection and retrieval system to evaluate the resources available, the developing needs, and the management options to utilize the available waters.

PART III

CHAPTER 9

WATER REQUIREMENTS FOR NAVIGATION AND RELATED CONSIDERATIONS

The Nation's waterways have always been important to commerce. In 1960 they carried 9 percent of the total commercial ton-miles being transported between cities; in 1974 they carried 11 percent.

Navigation in the United States is a complex mixture of (1) commercial and recreational traffic and (2) ownership, investment, and management interests with largely Federal provision of waterways and connecting facilities, state and local government provision of port facilities, and and private sector provision of the using ships and vessels. Navigation is a part of an overall National transportation network of water, railroad, motor carrier, and airway systems which compete for the Nation's passenger and freight business. The relatively inflexible routing and slow speeds of waterway transportation attract mostly high bulk, low value, or potentially hazardous commodities.

Development and management of the Nation's rivers, lakes, and intra-coastal waterways for navigation conflicts with competing interests. For example, successful navigable waterways require frequently spaced impoundments, periodic dredging of channels, and alteration of flow regimes, all of which affect fish and wildlife habitats, floodplain functions and flooding, water quality, and other water dependent activities.

Successful waterway transportation operates as a system of ports, waterways, and carriers which provide services of real value to the economy. It measures its growth in terms of increased commodity movements, but future growth must be attracted through improved and more flexible management of the whole system to reflect full costs and benefits to society. A waterway transportation system allocates its resources to nonstructural measures such as traffic scheduling, draft and tow limitations, demand estimation, facility planning, etc. as well as to structural improvements to grow in harmony with competing water supply and environmental interests as well as with other modes of transportation.

Rivers of North America were used for transportation before the rest of the world knew the continent existed. Early explorers, trappers, settlers, and traders found movement easier on water than on land even with the uncertainties produced by nature with either too little or too much water. Towns grew up on the coasts and rivers and trade moved on water. Rivers, especially the Ohio, provided easily accessible routes during the westward expansion. As the country and its commerce grew, there were more demands for river regulation and canals, and the first such improvements were made by private interests and states.

The first Federal activities in river control followed the Rivers and Harbors Act of 1824 in which Congress authorized improvements on the Ohio and Mississippi Rivers. The removal of snags and sand bars greatly reduced accidents on the rivers, but they did nothing to alleviate the drastic changes in river levels between wet and dry periods. Eventually a regulating dam was built in 1885 at Davis Island, about five miles below Pittsburgh. The dam could be raised during low flow to create a stable pool for navigation and lowered to give an open river when natural flow was adequate for navigation. The dam worked so well that additional dams were authorized and by 1929 a series of 50 locks and dams channelized the entire Ohio making it navigable at all times.

The relative importance of water transportation began to decline with the advent of railroads and the general unpredictability of navigation. However, Congress continued to authorize navigation improvements to insure low-cost, competitive transportation to move commodities and products efficiently in daily commerce and on those occasions when movement might be beyond the capacity of other carriers. Today the waterways provide competitive tarriffs for many of the Nation's agricultural, energy, and construction commodities.

The Nation's Existing Waterways

The Nation's recognized navigation system is composed of 26,700 miles of inland and intracoastal waterways, the Great Lakes-St. Lawrence Seaway system and the ports and harbors serving these waterways (Figure III-25). Waterways provide direct access to 131 of the Nation's largest cities and to almost all of the conterminous states. In Alaska, although use intensity is low, water provides access to many parts of the interior where there are no road or rail services.

The Mississippi River system is the largest and most improved component of the inland waterways with 9,000 miles of navigable channels (Figure III-26). The waterways of the Atlantic coast include the Atlantic Intracoastal Waterway (AIWW) and the New York New England Waterways with their tributaries a total of 7,000 miles of navigable channels with 65 percent having an authorized depth of 9 feet. The Gulf Intracoastal Waterway (GIWW) and tributaries contain 5,400 miles of navigable channels of which about one-half is authorized for at least 9 feet of depth. The Columbia-Snake River navigation system and the channels extending inland from San Francisco Bay total about 3,600 miles with 65 percent having a 9 foot authorized depth.

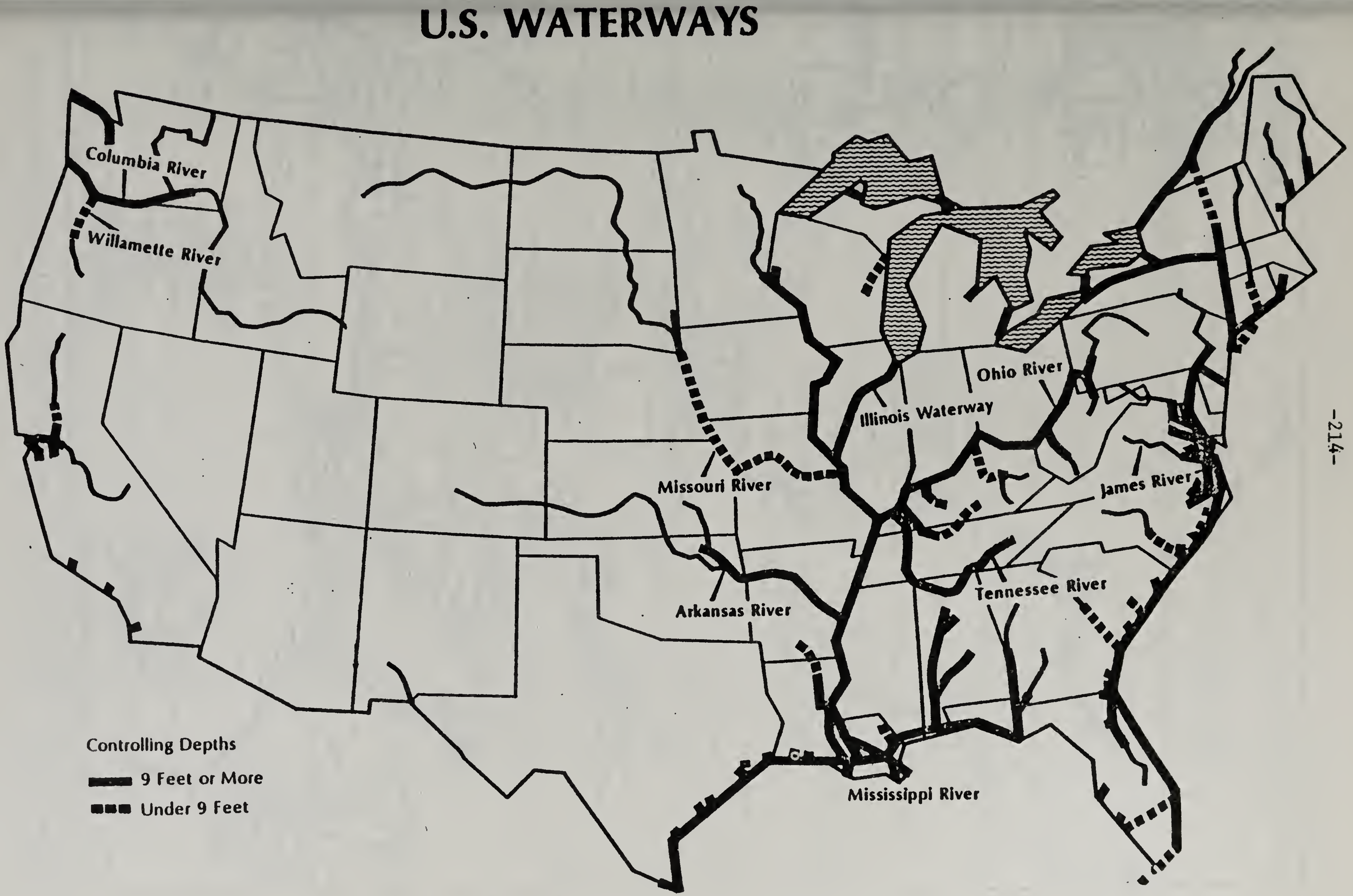
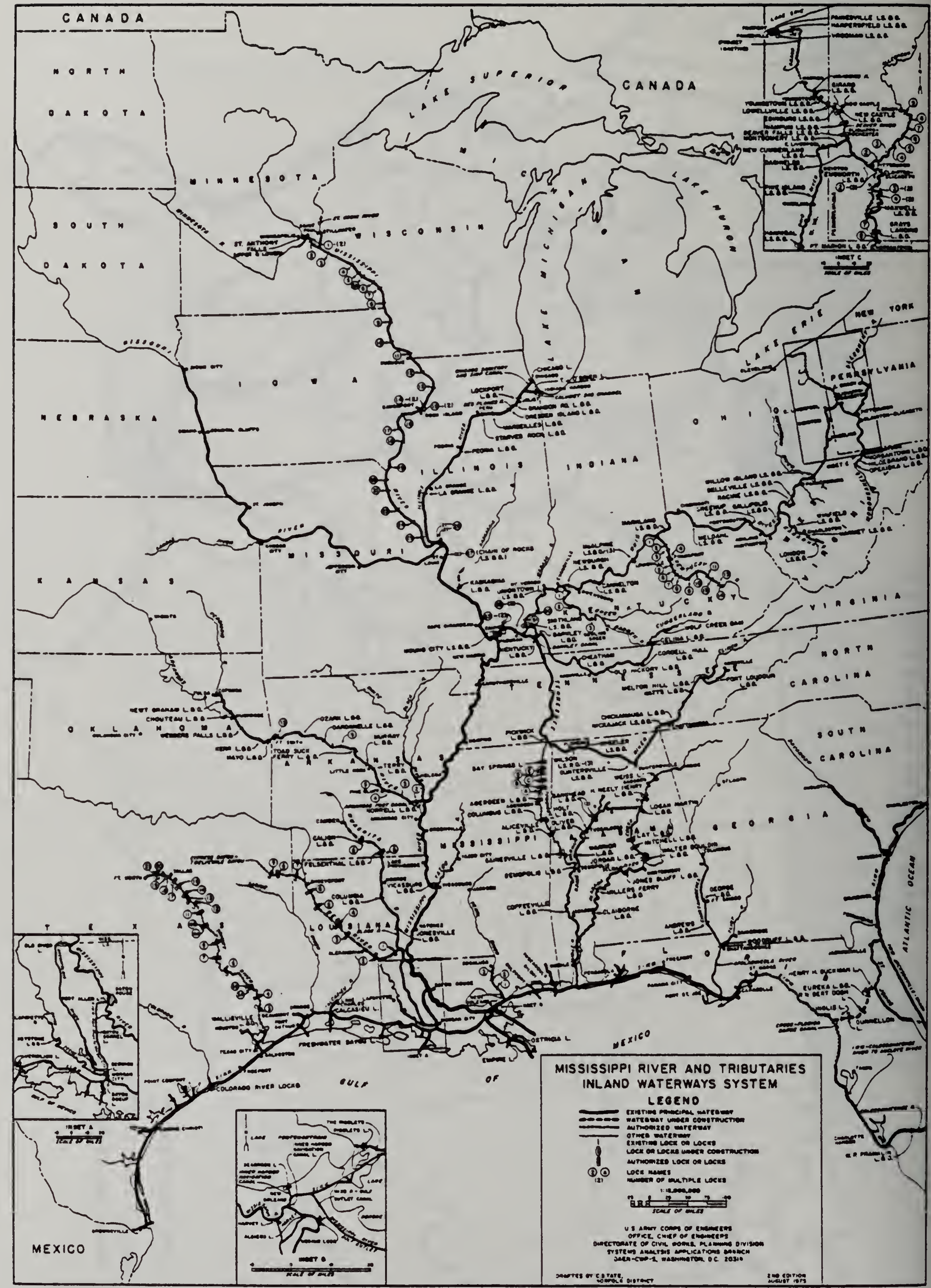

U.S. WATERWAYS
Columbia River
Willamette River
Missouri River
Illinois Waterway
Ohio River
James River
Arkansas River
Tennessee River
Mississippi River
Controlling Depths
9 Feet or More
Under 9 Feet

Figure III-25. THE NATION'S INTRACOASTAL, INLAND, AND GREAT LAKES WATERWAYS


CANADA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
WISCONSIN
LAKE SUPERIOR
CANADA
MICHIGAN
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
NEW YORK
PENNSYLVANIA
IOWA
NEBRASKA
ILLINOIS
INDIANA
OHIO
KANSAS
MISSOURI
KENTUCKY
VIRGINIA
NORTH CAROLINA
TENNESSEE
OKLAHOMA
ARKANSAS
SOUTH CAROLINA
MISSISSIPPI
ALABAMA
GEORGIA
TEXAS
LOUISIANA
FLORIDA
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
COLORADO RIVER LOCKS
INSET A
INSET B
INSET C
SCALE OF MILES
MISSISSIPPI RIVER AND TRIBUTARIES
INLAND WATERWAYS SYSTEM
LEGEND
EXISTING PRINCIPAL WATERWAY
WATERWAY UNDER CONSTRUCTION
AUTHORIZED WATERWAY
OTHER WATERWAY
EXISTING LOCK OR LOCKS
LOCK OR LOCKS UNDER CONSTRUCTION
AUTHORIZED LOCK OR LOCKS
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OFFICE, CHIEF OF ENGINEERS
DIRECTORATE OF CIVIL WORKS, PLANNING DIVISION
SYSTEMS ANALYSIS APPLICATIONS BRANCH
DAEN-CWP-S, WASHINGTON, D.C. 20314
DRAFTED BY C.D. TATE,
NORFOLK DISTRICT
2ND EDITION
AUGUST 1973

Figure III-26. MISSISSIPPI RIVER AND TRIBUTARIES INLAND WATERWAYS SYSTEM

The Great Lakes have a surface area of 95,000 square miles and 1,700 miles of navigable water connecting the Great Lakes System to the Atlantic Ocean. The main obstacles to navigation are in connecting channels between lakes. At Chicago the 9 foot deep Illinois Waterway joins Lake Michigan with the Mississippi River. This connection between the Great Lakes and the inland waterways allows an interchange of goods between both systems. Another connection with the Great Lakes is at Oswego, N.Y., where the state-operated Great Lakes to Hudson River Waterway enters the Lakes. This waterway, part of the New York State Barge Canal, provides a 13-foot channel between Lake Ontario and the Hudson River.

The Nation's Commerce - Waterborne and Other Modes

The Nation's waterborne commerce is about one-fourth of the total intercity freight as measured in ton miles and only about 16 percent of the net tons carried. Both measures show a steady decline in relative importance to other modes since 1949 (Table III-63). Actual ton miles and tons carried by water grew steadily, 62 and 88 percent respectively, from 1949 to 1974. However, non-waterborne intercity traffic grew faster over the same period at 140 percent in ton miles and 107 percent in net tons.

Inland waterways' intercity freight traffic grew faster than other types of waterborne traffic (Great Lakes and coastal traffic) over this 25 year post-World War II period. Inland waterways handled nearly six

Table III-63
HISTORICAL SUMMARY OF INTERCITY FREIGHT TRAFFIC
BY MODES AND WATERBORNE FREIGHT TRAFFIC BY TYPE OF WATERWAY, 1949-1974

Year	Total Intercity Freight	All Non-Waterborne 1/ Freight		All Domestic Waterborne Freight		Inland Waterways		Great Lakes		Coastal	
	billion ton miles	billion ton miles	Per-cent	billion ton miles	per-cent	billion ton miles	per-cent	billion ton miles	per-cent	billion ton miles	per-cent
1949	1138	777	68	361	32	42	4	98	9	221	19
1954	NA	NA	NA	NA	NA	83	NA	91	NA	NA	NA
1959	1549	1088	70	461	30	117	8	80	5	264	17
1964	1778	1291	73	487	27	114	8	106	5	237	13
1969	2117	1589	75	528	25	188	9	115	5	225	11
1974	2446	1861	76	585	24	247	10	107	4	231	9
	million net tons	million net tons		million net tons		million net tons				million net tons	
1949	2648	2175	82	473	18	166	6	146	6	161	6
1954	3234	2685	83	549	17	217	7	145	5	187	6
1959	3533	2914	82	619	18	282	8	131	4	206	6
1964	4365	3650	84	715	16	358	8	151	4	206	6
1969	4973	4134	83	839	17	461	9	161	3	217	4
1974	5388	4498	83	890	17	511	10	146	3	233	4

1/ Includes railway, truck, airway and oil pipeline freight (excluding mail and express since 1969) for both for-hire and private carriers.

Source: Transportation Facts and Trends, Transportation Association of America, Washington, D.C.

times more ton-miles of traffic in 1974 than in 1949 and about three times more net tons. These data indicate a propensity to move commodities over longer and longer distances on the inland waterway system.

Waterborne Commerce -- Foreign and Domestic

The commerce handled at United States ports includes both foreign cargoes (both imports and exports) and domestic shipments between U.S. ports. During 1974 the Nation's total waterborne commerce, including both foreign and domestic cargoes was 1.7 billion tons, an increase of more than 40 percent since 1964. Petroleum and related products are the predominant commodity traffic about 42 percent of the tonnage in both foreign and domestic waterborne commerce. The energy resources (petroleum and coal) together make up over 55 percent of the total waterborne commerce (Table III-64).

In 1974 foreign waterborne commerce, including imports and exports, was 764 million tons of which 497 million tons were imported and 267 million tons were exported. This was an increase of more than 80 percent in total commerce since 1964. Imports and exports through coastal ports were 474 and 239 million tons respectively, while imports and exports through Great Lakes ports were about 4 and 5 million tons respectively.

Table III-64
TOTAL, FOREIGN, AND DOMESTIC WATERBORNE COMMERCE BY MAJOR COMMODITY GROUPS WATER, RESOURCES REGIONS 1-18, 1974

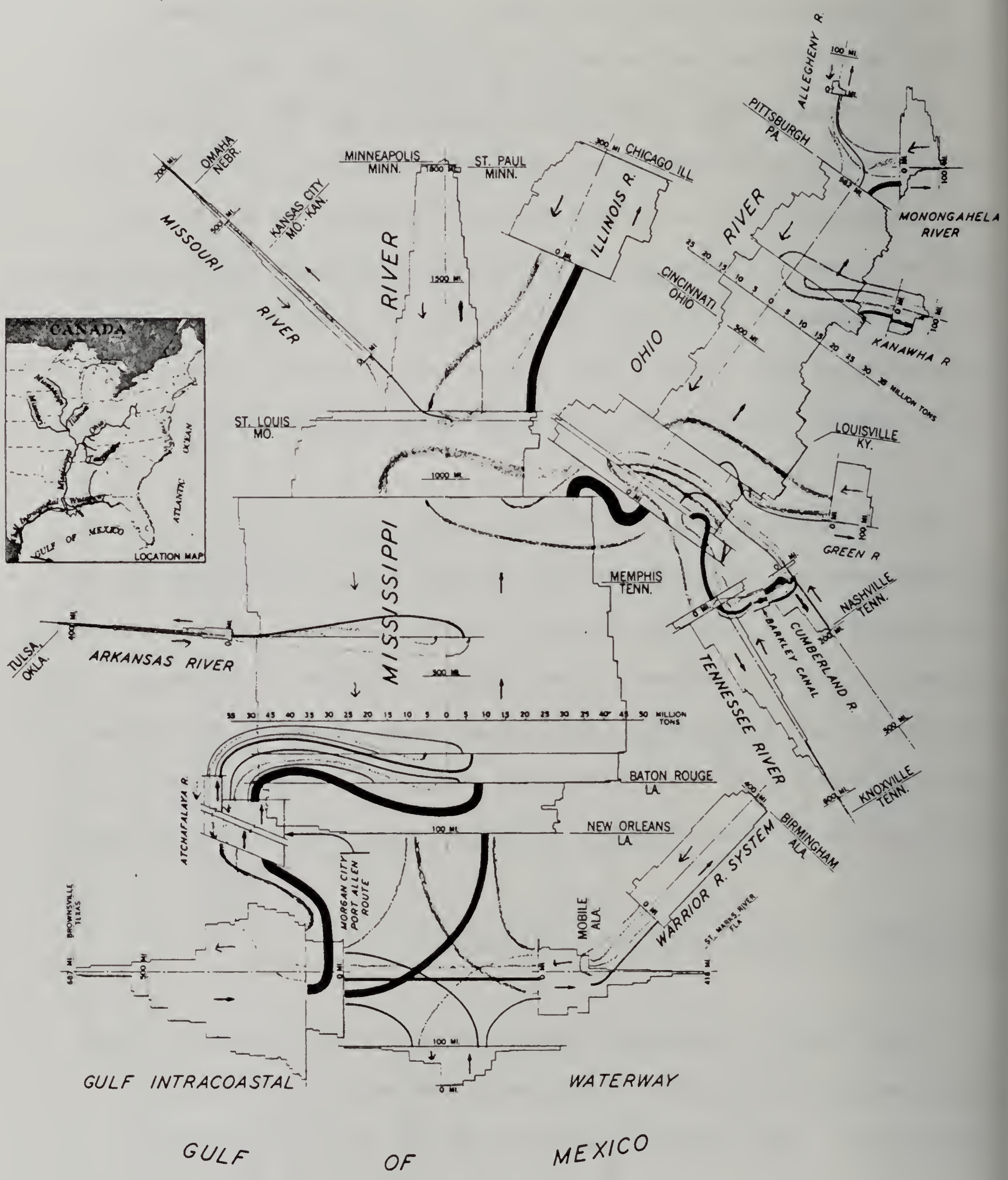
Commodity Group	Total Commerce		Foreign Commerce		Domestic Commerce	
	Million Tons	Percent	Million Tons	Percent	Million Tons	Percent
Petroleum and products	735.4	42.1	328.1	43.0	407.3	41.5
Coal and coke	228.8	13.1	81.2	10.6	147.6	15.0
Iron ore, iron and steel	171.2	9.8	79.6	10.4	91.6	9.3
Sand, gravel and stone	127.5	7.3	14.9	2.0	112.6	11.5
Grains	97.8	5.6	70.1	9.1	27.7	2.8
Chemicals	96.1	5.5	40.7	5.3	55.4	5.6
Logs and lumber	52.4	3.0	25.8	3.4	26.6	2.7
Seashells	17.5	1.0	0.0	0.0	17.5	1.8
All others	200.1	12.6	123.7	16.2	96.4	9.8
Total	1746.8	100.0	764.1	100.0	982.7	100.0

In 1974 domestic waterborne commerce, including only shipment within the United States, was nearly 983 million tons, about 56 percent of the total waterborne commerce and 20 percent over 1964. Of this, 511 million tons were internal or inland waterways traffic, 233 million tons were coastal traffic, 146 million tons were on lakes, 88 million tons were local, and 4 million tons were interritory (between U.S. territories). For this Assessment projections are based on the navigation and waterborne commerce 1975 figure of 501 million tons of internal traffic on the Mississippi River and the Gulf Intracoastal Waterway Systems.

The Mississippi River and Tributaries and the Gulf Intracoastal Waterway networks, which essentially form one system, carry most of the cargo moved on the waterways (Figure III-27). These two systems combined account for about 55 percent of the length, 70 percent of waterborne ton-mileage, and 85 percent of waterborne tonnage in the United States. The lower Mississippi between the mouth of the Ohio River and Baton Rouge carries the largest amount of traffic, more than 90 million tons.

The Waterway Commerce Assessment, 1975-2000

Total domestic waterborne freight traffic on the Mississippi River and Tributaries and the Gulf Intracoastal Waterway for 1975 was 501 million tons. This traffic is expected to grow by about 79 percent


ALLEGHENY R.
100 MI.
PITTSBURGH PA.
MONONGAHELA RIVER
CHICAGO ILL.
ILLINOIS R.
0 MI.
MINNEAPOLIS MINN.
ST. PAUL MINN.
1800 MI.
1500 MI.
OMAHA NEBR.
700 MI.
500 MI.
KANSAS CITY MO.-KAN.
MISSOURI RIVER
RIVER
CANADA
LOCATION MAP
GULF OF MEXICO
ATLANTIC OCEAN
OHIO RIVER
CINCINNATI OHIO
500 MI.
25 20 15 10 5 0 5 10 15 20 25 30 35 MILLION TONS
KANAWHA R.
LOUISVILLE KY.
GREEN R.
ST. LOUIS MO.
1000 MI.
MISSISSIPPI
MEMPHIS TENN.
NASHVILLE TENN.
CUMBERLAND R.
BARKLEY CANAL
TENNESSEE RIVER
KNOXVILLE TENN.
TULSA, OKLA.
400 MI.
ARKANSAS RIVER
500 MI.
55 50 45 40 35 30 25 20 15 10 5 0 5 10 15 20 25 30 35 40 45 50 MILLION TONS
BATON ROUGE LA.
NEW ORLEANS LA.
100 MI.
ATCHAFALAYA R.
MORGAN CITY PORT ALLEN ROUTE
BIRMINGHAM ALA.
WARRIOR R. SYSTEM
MOBILE ALA.
ST. MARKS RIVER FLA.
BROWNSVILLE TEXAS
687 MI.
500 MI.
416 MI.
100 MI.
0 MI.
GULF INTRACOASTAL WATERWAY
GULF OF MEXICO

INLAND FREIGHT TONNAGE ON THE MISSISSIPPI RIVER SYSTEM
AND THE GULF INTRACOASTAL WATERWAY 1974

Figure III-27. INLAND FREIGHT TONNAGE ON THE MISSISSIPPI RIVER SYSTEM AND GULF INTRACOASTAL WATERWAY, 1974

to 899 tons in 2000 (Table III-65). Petroleum and products comprised 41 percent of the traffic in 1975, but this traffic will grow only 46 percent by 2000 when petroleum will make up only about one-third of the freight. Coal and coke products traffic will increase by about 112 percent and make up 29 percent of the traffic in 2000. All other commodity traffic is projected to increase proportionately over this period with the two energy sources retaining together about two-thirds of the Mississippi River-Gulf Intracoastal Waterways traffic.

The regional characteristics of inland waterway navigation depends upon the types of economic activities located therein, either naturally or by virtue of the waterway system available. The Ohio and Upper and Lower Mississippi Regions originated 346 million tons of commerce in 1975, 70 percent of the total traffic (Table III-66). In 2000 these three regions are expected to originate 620 million tons of waterborne traffic, about the same proportion as in 1975. The other major waterway traffic region is the Texas-Gulf with about 100 million tons or one-fifth of the total in 1975. The largest rate of traffic increase is expected in the Tennessee Region although the total of 30 million tons by 2000 will represent only 3 percent of all waterway traffic. This increase will result largely from the expected opening of the Tennessee-Tombigbee segment in 1986.

Table III-65

PROJECTIONS OF DOMESTIC WATERBORNE TRAFFIC BY COMMODITIES FOR THE MISSISSIPPI RIVER AND TRIBUTARIES AND GULF INTRACOASTAL WATER SYSTEMS

Commodity	1975		1985		2000	
	Million Tons	Percent	Million Tons	Percent	Million Tons	Percent
Petroleum and products	207	41	242	37	303	34
Coal and coke	123	25	187	29	261	29
Iron ore, iron and steel	9	2	12	2	16	2
Sand, gravel and stone	27	5	31	5	40	4
Grains	28	6	33	5	47	5
Logs and lumber	1	<1	2	<	3	<1
Chemicals	38	8	56	9	100	11
Shells	13	3	16	2	20	2
All others	55	11	74	12	112	12
Total	501	100	648	100	899	100

Table III-66

SUMMARY OF WATERBORNE COMMERCE ON THE MISSISSIPPI RIVER SYSTEM AND GULF INTRACOASTAL WATERWAY BY COMMODITIES AND WATER RESOURCES REGIONS OF ORIGINS - 1975, 1985, 2000

(MILLIONS OF TONS)

Regions	All Commodities			Percent			Petroleum			Coal and Coke			Iron Ore Iron Steel			Sand Gravel Stone			Grains			Chemicals			Shells			Other		
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000
South Atlantic-Gulf	31	37	55	6	6	6	15	18	22	6	7	9	3	3	6	2	2	4	<1	<1	1	1	2	5	1	1	2	2	3	4
Great Lakes	13	16	23	3	3	3	3	4	5	1	1	1	1	2	2	2	3	3	1	1	2	1	2	3	0	0	0	3	4	7
Ohio	128	159	219	26	25	24	12	13	16	90	112	156	2	3	3	13	15	18	2	2	4	4	5	9	0	0	0	6	9	13
Tennessee	7	9	30	1	1	3	<1	<1	<1	3	4	21	<1	<1	1	2	2	2	<1	<1	<1	1	1	1	0	0	0	1	1	3
Upper Mississippi	63	110	141	13	17	16	6	8	10	18	57	67	<1	1	1	4	5	7	21	26	34	1	1	3	0	0	0	11	15	23
Lower Mississippi	155	190	260	31	29	29	93	108	135	4	5	6	2	3	3	2	2	3	2	2	3	17	25	43	9	11	13	26	35	53
Missouri	2	2	2	1	1	1	0	0	0	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	1	2	<1	<1	<1	0	0	0	1	1	2
Arkansas-White-Red	1	1	2	1	1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	1	1	<1	<1	<1	<1	<1	<1	0	0	0	1	1	1
Texas Gulf	100	123	165	20	19	18	78	91	114	1	1	1	1	1	1	1	1	2	1	1	1	13	20	35	3	4	5	4	6	8
Rio Grande	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1
Total	501	648	899	100	100	100	207	242	303	123	187	261	9	12	16	27	31	40	28	33	47	38	56	100	13	16	20	56	76	115

Waterborne cargo in the South Atlantic-Gulf Region consists largely of energy materials with petroleum and coal making up two-thirds of the traffic. The Ohio Region's waterway traffic is 70 percent coal and coke with about equal tonnages of petroleum and sand-gravel-stone (about 10 percent each). The major commodity traffic on the Upper Mississippi is grain (one-third of the commerce) followed by coal (29 percent) and petroleum (10 percent). This region originates three-fourths of all the grain traffic on the inland waterway system. Increased agricultural exports would increase this traffic proportionately.

The major traffic commodities on the Lower Mississippi are petroleum (60 percent) and chemicals (11 percent). The chemicals traffic may increase by 2.5 times but the petroleum traffic will likely increase only about 45 percent by 2000. Likewise, the predominant traffic on the Texas-Gulf waterways is petroleum (78 percent) and chemicals (13 percent). These two regions account for 83 percent of the waterborne petroleum and 79 percent of the waterborne chemicals carried on the domestic waterway system. Small amounts of traffic (about 30 million tons) originate on the Columbia-Snake system (Pacific Northwest Region), but they are not included in the data for the Mississippi River System and Gulf Intracoastal Waterway.

Major navigation improvements are underway in the South Atlantic-Gulf Region to accommodate expected growth. Although it originated only 31 million tons in 1975 the total waterborne tonnage, foreign and domestic was 230 million tons. The new improvements include the Tennessee-Tombigbee now under construction and significant port improvements.

Maintenance of these waterways to nine foot channel depths under environmentally acceptable conditions will be a continuing problem for navigation in this region.

The Ohio River Basin growth in waterborne commerce, nearly doubling by 2000, will require extensive structural modernization to bring the total system up to modern tow standards with 1200 foot locks. The Texas-Gulf region will require considerable financing for facilities and maintenance of waterways to accommodate the 1975 level of 200 million tons of cargo (100 million internal) and the 65 percent growth for 2000.

Non-Cargo and Passenger Uses of the Inland Waterways

Recreational boating has become an important and rapidly growing activity on the Nation's waterways with an estimated 8.3 million boats in use in 1974 (Table III-67). Recreational boating is providing cargo waterway users with increased competition for the use of waterways. The greatest impact is at points of congestion such as locks and fleeting areas. Pleasure boat docking sites also compete with cargo-commercial uses of valuable and limited water front property. In 1975 non-cargo (largely recreational) lockages amounted to as much as one-half of all lockages at many locks. This indicates increasing pressures on operating costs for locks and commercial uses as density of traffic and congestion increase.

Table III-67
SELECTED RECREATIONAL BOATING STATISTICS BY REGION, 1974

Regions	Total Boats All Types	Total Operators	Total Passengers	Boat Hours
Great Lakes	2,034,456	3,889,416	5,960,956	256,594,351
Mid-Atlantic	1,364,575	2,692,361	3,848,101	225,256,557
Gulf Coast	1,523,664	2,369,450	4,311,969	287,577,859
New England	1,222,407	2,976,551	3,508,303	186,808,304
West Coast	963,867	2,074,961	3,113,290	86,069,613
Mid-West/Mountains	684,213	1,380,576	2,093,691	59,593,351
East Central	543,161	987,187	1,613,188	87,122,812
Total	8,336,343	16,370,502	24,449,950	1,189,022,661

Source: U.S. Coast Guard

While transportation of passengers by water is relatively small in comparison with other modes, current records indicate that there are more than 3,800 inspected U.S. vessels in the passenger trade, mostly small ferry and passenger vessels. While available passenger statistics are not complete over 20 million persons are carried by these vessels in 1974. An estimated 4,000 other vessels carry fewer than seven passengers each and are not required to be inspected. The decline in use of larger passenger vessels appears to have leveled off with tourist cruise ships, mostly foreign, experiencing an increase in passengers. Local and intercity passenger movements on the waterways are expected to increase between 1975 and 2000, but no special problems are foreseen.

Navigational Water Requirements

Navigation is a nonconsumptive water user. The navigation system needs a body of water of defined depth sufficient to maintain acceptable vessel operations (loads, tows, and speeds). In the open rivers navigation needs are adjusted to the natural regime of the water flow. Improvement of navigation conditions by dredging and other means, though essential for water transportation, are limited by river hydraulics, benefit-cost expectations, and environmental considerations.

Streamflows required to support navigation are generally less than those needed to maintain the quality of water, aquatic habitats, or other instream purposes. The lower sections of the Missouri, Mississippi, and Columbia Rivers, which are basically natural river regimes, may be exceptions to this general statement during low flow periods.

The streamflow required for navigation is greatly dependent on the degree to which the waterways are channelized, the depth being maintained, the number of locks, and the degree to which lockage water is pumped back to upper pools. Increasingly large flows of water will be required in the future to maintain suitable water quality, and to meet instream flow needs for fish and wildlife. In most water resource regions, the water required for navigation will be less than the requirements for other instream purposes, especially for fish and wildlife. Maintenance of these instream flow approximations (IFAs) will not necessarily preclude dredging and channelization to maintain navigability in most waterways.

Navigation and Related Resources

The principle problem for waterways transportation in the future will be that of developing and maintaining a viable and efficient waterway system as as integral part of the Nation's transportion system on in concert with recreation, fish and wildlife, commercial fishing, and other environmental considerations. The largest factor of uncertainty is that of dredging and the associated spoil disposal. Constraints on ocean dumping, diked wetlands, and other disposal methods have greatly increased the cost of maintaining navigation channels. Such costs may be especially difficult to meet for those instances where state and local governments are obligated to provide the dredge material disposal sites. These environmental and associated cost conditions directly confront the need for channel and port enlargements to meet increased traffic projections for commercial navigation.

Future Navigation Systems

The projected commercial traffic for 1985 and 2000 is based on continued free use of the waterways. It now seems likely that some system of charges for the use of the waterways and/or facilities will be adopted and implemented. Study results vary concerning the impact of charges on navigation traffic.

The waterway system of the United States is essentially complete except for certain connecting links such as the Tennessee-Tombigbee and the Kaskaskia Rivers waterways. Future improvements will include the completion of several previously authorized waterways such as the Smithland lock and dam (Ohio River), Lock and Dam 26, on the Mississippi River Vermilion and Port Allen Locks, Gallipolis, and others, but mostly efforts will be on continued modernization. A limited number of improvements in port and harbor approaches may be made. Widening and deepening of coastal harbor and channel dimensions will be limited by considerations such as the high cost of improvements and environmental concerns. Channel and bridge restrictions will continue to constrain system capacity through their effects on maximum tow size and speed. One-way only traffic is required now at some of these congested points. Major capacity constraints exist now or will develop before 1990 at various points on the Upper Mississippi, Ohio, Kanawha, and Monongahela Rivers; the Gulf Intracoastal waterway; and the Illinois waterway.

It is uncertain whether several authorized navigation projects can be completed before 2000. These projects include: the Gulf Intracoastal Waterway from St. Marks to Tampa, Florida, the Cross Florida Barge Canal (recently deauthorized for environmental concerns), the Coosa River project, the Illinois Waterway Duplicate Locks, the Red River in Louisiana and Texas, and the Trinity River navigation project in Texas.

However, harbor and port facilities for special situations such as petroleum handling will be funded and constructed. With the exception of Seattle, no U.S. port will be accessible to fully loaded super-ships; very large crude carriers (VLCC) of 140,000 deadweight tons and ultra large crude carriers (ULCC) of 300,000 or more deadweight tons. A "new" domestic trade route will be established between Valdez, Alaska and west coast ports for transport of oil from the southern terminus of the Trans-Alaskan Pipeline System to refineries in the lower 48 states. Two off-shore oil terminals are expected to be built in the Gulf of Mexico. These terminals (LOOP and SEADOCK), the first to be built off the U.S. coast, will have the capability of handling the largest tankers now afloat (540,000 deadweight tons, 90-foot draft). These offshore terminals will be used primarily for receipt of foreign oil for transhipment by pipeline ashore. The continued migration of population to coastal areas and the considerable non-resident interest in the natural aspects of the coastal and river areas will exert increasing pressures through the noncommercial uses of the system. In addition, certain consequences from construction activities which increase erosion and sedimentation may require even more maintenance dredging or new nonstructural alternatives to solve commercial navigation problems.

PART III

CHAPTER 10

WATER REQUIREMENTS FOR FISH AND WILDLIFE AND RELATED INSTREAM FLOWS

Fish and wildlife populations are valued as commercial, sport, and aesthetic resources, but they also serve as "environmental barometers", indicating what the condition of the Man's future will be. Fish and wildlife are dependent upon their habitat and are at the mercy of man's use of it. Observations and data examined in the Second Assessment indicate substantial impacts to riverine ecosystems, wetland and coastal ecosystems, and upland ecosystems have occurred and will continue to occur.

Water requirements for fish and wildlife are based on instream flows and amounts of water necessary for maintaining non-riverine aquatic and terrestrial ecosystems. These water requirements are closely related to and interdependent with other instream requirements such as recreation, navigation, hydro-power generation, and ecosystem maintenance. In addition, water management activities for flood control, erosion and sedimentation control, and irrigation greatly affect the success of fish and wildlife, especially in those situations where the needs become competitive rather than complementary.

In many instances water management problems for fish and wildlife are accentuated by lack of knowledge or insensitivity concerning the biologic and hydrologic relationships necessary to maintain the Nation's valuable fish and wildlife habitats. A better job could be done to manage streamflows, estuaries, lakes, reservoirs, and aquifers to enhance fish and wildlife without unacceptable impacts on the other functional uses of the Nation's waters. Progress is being made toward integrating fish and wildlife water needs with other functional water uses to avoid the costly and limited effectiveness of mitigation as the alternative for considering fish and wildlife in the Nation's water management plans.

The Fish and Wildlife Function

The fish and wildlife resources of the United States are diverse and occur in nearly all habitats except those intensively influenced by man. The value of fish and wildlife resources to the human population takes many forms. The 1975 Survey of Hunting and Fishing shows that over 74 million Americans over 9 years of age engaged recreational hunting and fishing. They spend over 21 billion dollars in retail sales of hunting and fishing equipment and other necessary economic goods and services. Non-consumptive uses of fish and wildlife resources include bird watching, nature study, and photography. In all, fish and wildlife related activities attract 95.9 million participants.* These statistics tend to overlook such intangible values as the thrill of observing wildlife as an unexpected embellishment of our everyday activities. Commercially important fish and wildlife resources include fur animals; anadromous fish such as salmon, shad; and striped bass; resident fish such as drum, catfish, and carp; and the estuarine and near-shore marine fish and shell fish resources.

Perhaps in the long term the most valuable use of fish and wildlife populations is as an index of man's well-being. "The composition and condition of fish and wildlife populations can serve man as a barometer of the quality of the environment for man . . ." since they are highly sensitive to environmental change.** No matter what type of environmental modification occurs -- whether one alters stream temperature or flow regime, drains wetlands, channelizes a water course, clears a forest, or changes land uses, there is going to be an immediate effect upon fish and wildlife.

Dependence Upon Habitat

Unlike man, wildlife populations do not have the ability to ship food supplies from one place to another, to manufacture shelter or erect it at the location of their choice and (except for certain migrating species) to rapidly transport themselves from one place to another. Animals are totally dependent on their habitat. For most species, their habitat is dominated by type, form, and density of the vegetation--either the native species or the cultured species of agriculture. The habitats most vital for the life cycles of the organisms, and which support greater populations of the animals are the aquatic and riparian habitats associated with the marshes, rivers, and coastlines.

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* U.S. Fish and Wildlife Service, 1975 National Survey of Hunting and Fishing, Washington, D.C.

**Wildlife--The Environmental Barometer, Wildlife Management Institute, Washington, D.C.

Water is just as important for animals as it is for man; but again, animals do not possess the capacity to transport water to the locations where it is needed. Thus, the animals are dependent upon the habitat provided by the existence of water nearby. Our surface water resources support plant and animal life in abundance. Our bare and rocky areas are virtually lifeless by comparison. Fish and wildlife are renewable resources. However, a healthy ecosystem is essential to their renewal. Proper management of land and water resources is vital to maintenance of a health ecosystem.

Endangered Species

Since the First Assessment, concern about the loss of viable populations of plants and animals resulted in enact-ment of the National Environmental Policy Act of 1969, the Endangered Species Act of 1973, and other protective measures. This trend toward enactment of protective legislation is evidence of the emerging environmental enlightenment of the public and our political leadership.

The Endangered Species Act of 1973 (Public Law 93-205) has as its stated purpose the conservation of the ecosystems and habitats upon which endangered and threatened species depend for their existence. Endangered species are those which are in danger of extinction. In most cases, the danger of extinction is attributable either directly or indirectly to human influences. Threatened species are those which may become endangered in the foreseeable future.

Endangered species need protection because of their aesthetic value, potential pharmaceutical benefits, and because each species plays a unique role in the overall environment especially in the functioning of the ecosystems in which they live. More than 150 species of higher animals in the United States (mammals, birds, reptiles, amphibians, and fishes) have been officially listed as endangered (Figure III-28). See also Appendix I of the Nationwide Analysis.

The Fish and Wildlife Service is evaluating data for designating "critical habitat" for the protection of these animal species, as well as for insects, crustaceans, molluscs, and a large number of plants

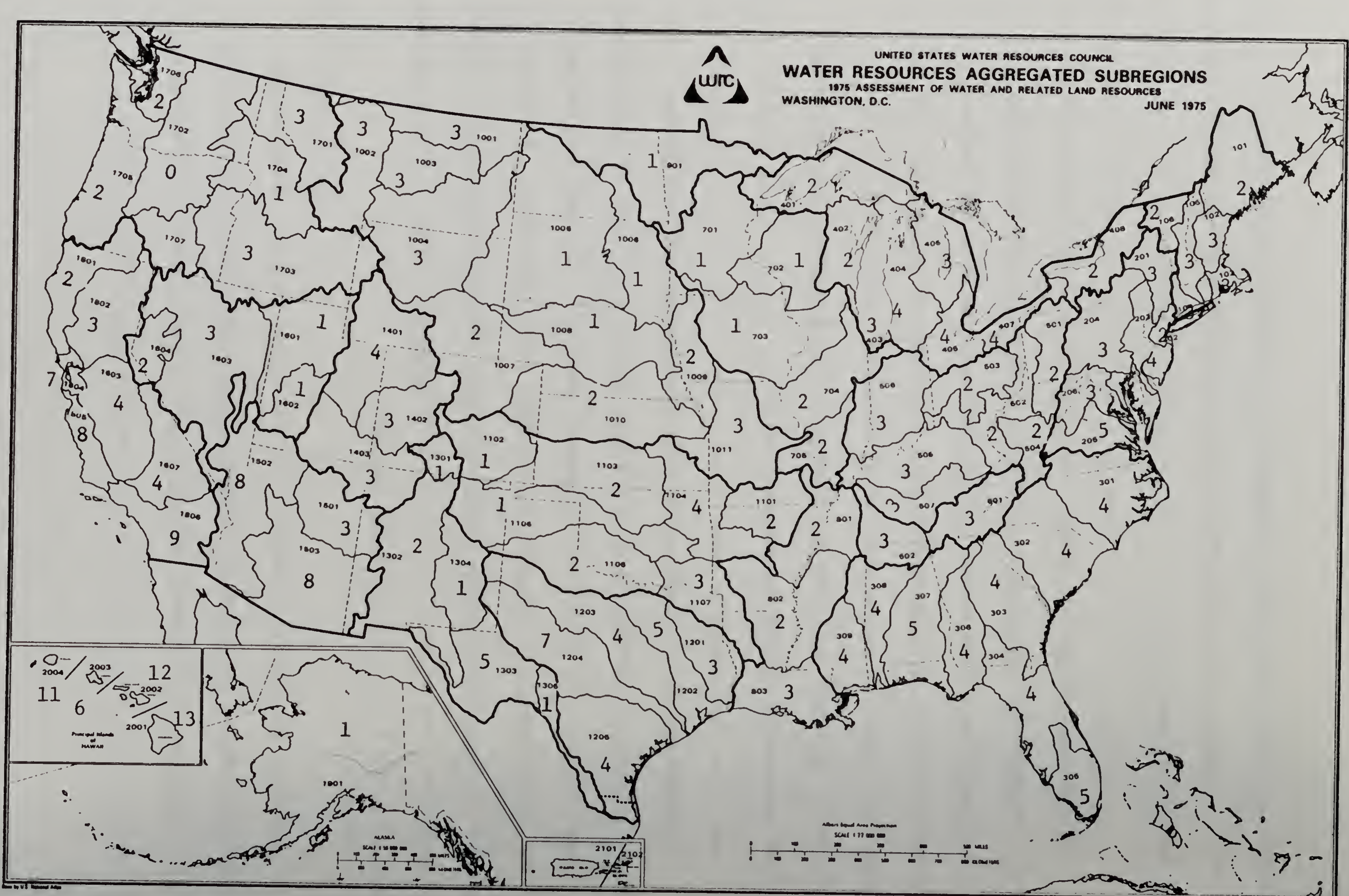

UNITED STATES WATER RESOURCES COUNCIL
WATER RESOURCES AGGREGATED SUBREGIONS
1975 ASSESSMENT OF WATER AND RELATED LAND RESOURCES
WASHINGTON, D.C.
JUNE 1975
WRC
Principal Islands of HAWAII
ALASKA
Albers Equal Area Projection

Figure III-28. NUMBER OF ENDANGERED SPECIES BY AGGREGATED SUBREGION AS OF OCTOBER 1976

which may be listed as endangered or threatened in the near future. Critical habitat of any species is viewed as the area(s), together with contained biological and physical elements, which are necessary for that species' survival. Only those actions within the critical habitat which would jeopardize the species' continued existence (as determined by consultation with the Fish and Wildlife Service) are affected by the Act.

The Act requires all Federal departments and agencies to take no action that would adversely affect the survival of endangered or threatened species or their critical habitat. Furthermore, all Federal departments and agencies are encouraged to conduct programs for the conservation and recovery of listed species. The large number and broad geographical dispersal of the species whose preservation is mandated by Congress may impose potential constraints on water resource projects and other developmental activities. Although the Act may have been championed by some as a basis for stopping water development; such effort would be an inappropriate use of the law. Rather, it should be used to expedite the recovery of the species--which might involve selection of alternative sites or delaying development until adequate recovery has been accomplished. The costs of such delay and the necessary recovery measures are indicative of the true cost of past careless decisionmaking which has allowed a species to become endangered or threatened. It is far cheaper to accommodate habitat preservation, enhancement, or mitigation measures into man's development activities before our native species are so depleted that the Endangered Species Act must be brought into play.

Fish and Wildlife Habitats

Problems emanating from man's uses of his environment are often characterized as those that involve the water resources and those that involve the land. Actually, these are closely related and cannot adequately be considered in isolation for long. To assist in assessing the state of our ecosystems, let us consider three major ecosystem types: riverine, wetlands and coastal, and upland.

Riverine Ecosystems

A stream is a riverine ecosystem. It can be defined as a natural water course containing flowing water at least part of the year and supporting a biotic community of aquatic plants and animals. It usually includes, in addition to the stream channel, a zone of riparian vegetation dependent upon surface or subsurface flow and a flood plain which is formed by the kinetic energy of the stream during periods of high flow.

The values of riverine ecosystems and their fish and wildlife populations were recognized by the Indian, the explorer, and the settler. Today's modern society continues to make utilitarian use of streams, but it is increasingly demanding retention of the fish and wildlife values associated with streams. The thousands of miles of streams in this Nation are as diverse as the climate and physiography of the Nation. Classification of streams according to their nationally important fishery values is useful as a guide to planners. Establishing priority streams for use in planning can, in siting developments, reduce environmental losses, mitigation costs, and planning study costs.

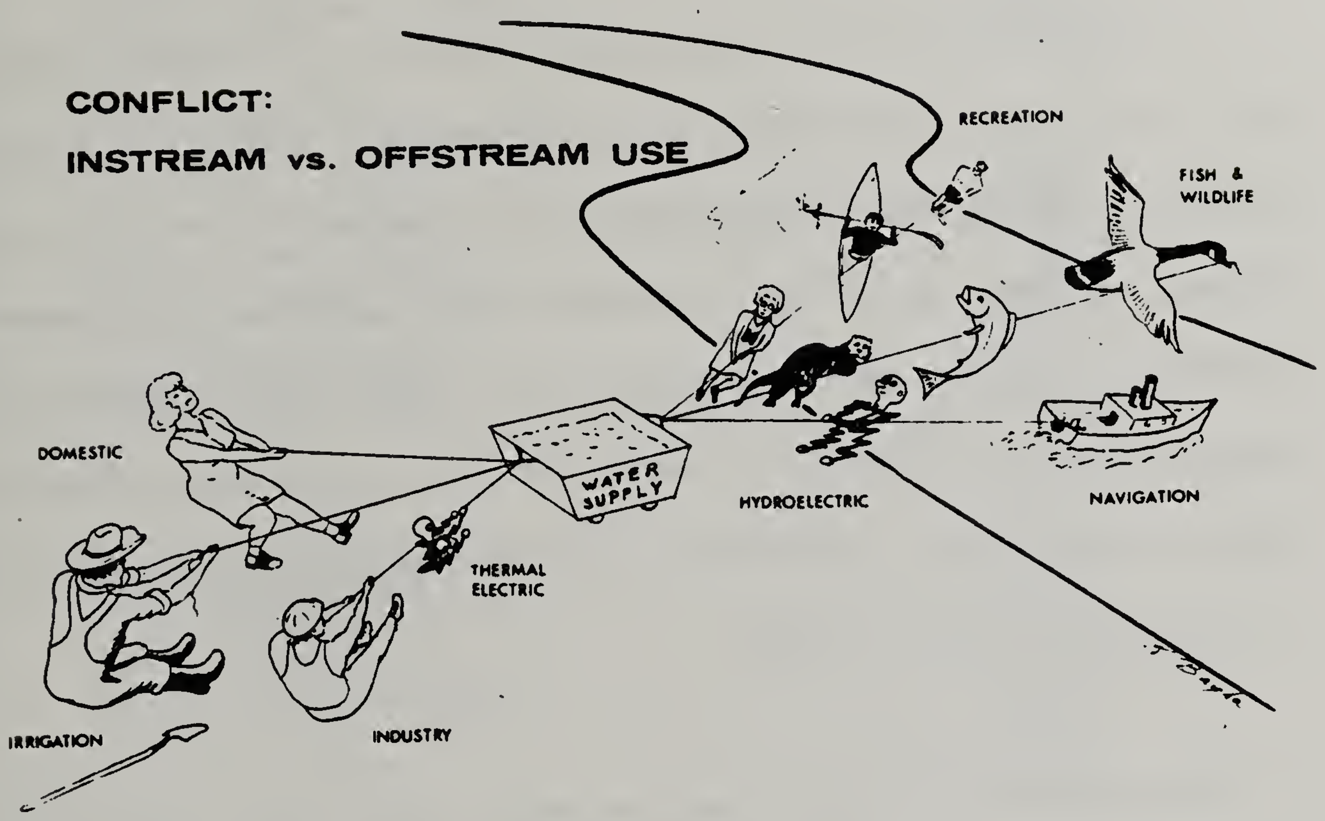
While there are several Federal programs mandated by law which call for identification and preservation of nationally significant streams, there is no official nationwide display of such streams. In an initial attempt to classify rivers, a series of maps for the Second Assessment were compiled from existing state classification systems and information supplied by the Fish and Wildlife Service's Ecological Services field personnel. The criteria used included the presence of nationally significant recreational fisheries and reproduction habitat for nationally significant anadramous species. This system was further expanded to include riverine habitat of endangered species, selected National Wildlife Refuges, stream reaches included or proposed for inclusion in the Federal Wild and Scenic Rivers System, as well as nationally significant inland river commerical fisheries. In addition, results available from the Fish and Wildlife Service's ongoing stream priorities project were added for nine states. This improved map is available as a separate product of the Assessment. It serves as a statement of current perception of stream priorities and as a starting point for further refinement for the purposes of improving the management of the Nation's waters. This first generation map should be given broad review, perhaps through EPA's program for review of state water quality standards so that refinements can be made. Then a second generation map should be published to better serve the Nation's water resource planners, developers, and managers in recognizing critical fish and wildlife values and their locations.

Water allocation problems basically stem from the fact that past decisions regarding this vital resource placed constraints on future choices. With limited water resources available, we are now experiencing new water demands (e.g., environmental and energy) in the face of long standing vested interests (Figure III-29).

> "Man's use of water falls into two modes: (1) instream uses such as hydropower generation, navigation, water conveyance, waste assimilation, recreation, aesthetics, estuarine inflow, and aquatic and riparian ecosystem maintenance (which includes support of the varied life forms), and (2) offstream uses such as irrigated agriculture, municipal water requirements, and industrial water requirements (including cooling water for energy plants). The allocation of the available water supply

Figure III-29

CONFLICT: INSTREAM VS. OFFSTREAM USE


CONFLICT:
INSTREAM vs. OFFSTREAM USE
RECREATION
FISH & WILDLIFE
DOMESTIC
WATER SUPPLY
HYDROELECTRIC
NAVIGATION
THERMAL ELECTRIC
IRRIGATION
INDUSTRY

> among these uses has always been a volatile issue in the West; and in certain areas of the East it is emerging as an issue of major importance." *

- Instream Flow Approximations

The First Assessment, did not address instream flows due to lack of data but stated "in future assessments, a more complete analysis of the adequacy of flow for instream uses will be undertaken." **

In fulfilling that promise, this Second Assessment provides the first nationwide examination of instream flow conditions and the implications of accelerated offstream uses of water. This was accomplished through an analysis of the consumptive and nonconsumptive water "requirements" in relation to water supply for each of 106 aggregated subregions (see Part IV). In conjunction with these flow analyses a set of numbers was needed to represent the instream flow requirements for fish and wildlife (Table III-68).

An analysis of the collective water requirements of a group of streams comprising a major river basin cannot be made without sacrifice in precision. Furthermore, describing instream flow needs at the

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* Bayha, Keith D. and William H. Honore. Water: The Next National Crises? Outdoor Recreation Action, No. 43, Spring 1977, pp 43-44 Bureau of Outdoor Recreation, U.S. Department of the Interior, Washington, D. C.

** Water Resources Council, 1968. Nation's Water Resources--The First National Water Assessment. Washington, D.C.

Table III-68
Instream Flow Approximations (IFA) for Fish and Wildlife by Aggregated Subregions

Region/Subregion	Instream Flow Approximations at Outflow Point (Million Gallons Per Day)
New England	
Northern Maine (0101)	33,350
Saco-Merrimack (0102)	8,810
Mass-Rhode I-Coastal (0103)	4,003
Housatonic-Thames (0104)	4,218
Connecticut River (0105)	10,980
Richelieu (0106)	7,640
Mid Atlantic	
Upper Hudson (0201)	11,010
Lower Hudson-LI-NNJ (0202)	13,870
Delaware (0203)	13,830
Susquehanna (0204)	21,390
Up/Lower Chesapeake (0205)	12,330
Potomac (0206)	7,420
South Atlantic Gulf	
Roanoke-Cape Fear (0301)	18,553
Pee Dee-Edisto (0302)	22,593
Savannah-St Marys (0303)	19,474
St Johns-Suwannee ((0304)	15,058
Southern Florida (0305)	6,590
Apalachicola (0306)	19,033
Ala-Choctawhatchee (0307)	35,809
Mobil-Tombigbee (0308)	36,110
Pascagoula-Pearl (0309)	15,435
Great Lakes	
Lake Superior (0401)	8,638
NW Lake Michigan (0402)	8,730
SW Lake Michigan (0403)	875
E Lake Michigan (0404)	13,992
Lake Huron (0405)	6,410
St Clair-W Lake Erie (0406)	4,863
Eastern Lake Erie (0407)	4,028
Lake Ontario (0408)	16,415
Ohio	
Ohio Headwaters (0501)	17,255
Upper Ohio-Big Sandy (0502)	55,294
Muskingum-Scioto-MI (0503)	9,613
Kanawah (0504)	9,209
Ky-Licking-GR-Ohio (0505)	160,520
Wabash (0506)	14,617
Cumberland (0507)	18,968
Tennessee	
Upper Tennessee (0601)	21,747
Lower Tennessee (0602)	38,480

Note: For derivation of these data see Fish and Wildlife and Related Resources Requirements Appendix.

Table III-68 (Continued)
Instream Flow Approximations (IFA) for Fish and Wildlife by Aggregated Subregions

Region/Subregion	Instream Flow Approximations at Outflow Point (Million Gallons Per Day
Upper Mississippi	
Mississippi Headwaters (0701)	8,700
Bk-Root-Chippewa-WIS (0702)	24,608
Rock-Miss-Des Moines (0703)	38,250
Salt-Sny-Illinois (0704)	57,250
Low/Up Mississippi (0705)	110,750
Lower Mississippi	
Hatchie-Miss-St Fran (0801)	284,794
Yazoo-Miss-Ouachita (0802)	319,540
Mississippi Delta (0803)	359,033
Souris-Red-Rainy	
Souris-Red-Rainy (0901)	3,673
Missouri	
Mo-Milk-Saskatchewan (1001)	4,542
Missouri-Marias (1002)	3,650
Missouri-Musselshell (1003)	4,192
Yellowstone (1004)	7,360
Western Dakotas (1005)	11,063
Eastern Dakotas (1006)	12,543
NO/SO Platte (1007)	2,159
Niobrara-Platte-Loup (1008)	3,285
Middle Missouri (1009)	20,906
Kansas (1010)	3,706
Lower Missouri (1011)	33,958
Arkansas-White-Red	
Upper White (1101)	13,199
Upper Arkansas (1102)	431
Arkansas-Cimarron (1103)	2,867
Lower Arkansas (1104)	18,180
Canadian (1105)	2,347
Red-Washita (1106)	2,020
Red-Sulphur (1107)	14,790
Texas-Gulf	
Sabine-Neches (1201)	8,560
Trinity-Galveston Bay (1202)	6,210
Brazos (1203)	3,360
Colorado (Texas) (1204)	1,357
Nueces-Texas-Coastal (1205)	3,430
Rio Grande	
Rio Grande Hdwaters (1301)	347
Middle Rio Grande (1302)	833
Rio Grande-Pecos (1303)	1,360
Upper Pecos (1304)	298
Lower Rio Grande (1305)	2,287

Table III-68 (Continued)
Instream Flow Approximations (IFA) for Fish and Wildlife by Aggregated Subregions

Region/Subregion	Instream Flow Approximations at Outflow Point (Million Gallons Per Day
Upper Colorado	
Green-White-Yampa (1401)	3,056
Colorado-Gunnison (1402)	3,623
Colorado-San Juan (1403)	7,947
Lower Colorado	
Little Colorado (1501)	200
Lower Colorado Main Stem (1502)	6,864
Gila (1503)	676
Great Basin	
Bear-Great Salt Lake (1601)	3,738
Sevier Lake (1602)	1,092
Humboldt-Tonopah Des (1603)	2,137
Central Lahonton (1604)	1,210
Pacific Northwest	
Clark Fort-Kootenai (1701)	19,209
Upper/Mid Columbia (1702)	89,094
Upper Central Snake (1703)	9,048
Lower Snake (1704)	21,533
Coast-Lower Columbia (1705)	178,673
Puget Sound (1706)	34,249
Oregon Closed Basin (1707)	1,082
California	
Klamath-N Coastal (1801)	16,597
Sacramento-Lahontan (1802)	9,077
San Joaquin-Tulare (1803)	2,841
San Francisco Bay (1804)	2,250
Central Calif Coast (1805)	1,030
Southern California (1806)	343
Lahontan South (1807)	992
Alaska	
Alaska (1901)	859,000
Hawaii	
Hawaii County (2001)	2,154
Maui County (2002)	926
Honolulu County (2003)	294
Kauai County (2004)	1,216
Caribbean	
Puerto Rico (2101)	3,706
Virgin Islands (2102)	-0-

outflow point of an area as large as an aggregated subregion can, at best, only indicate conditions in the immediate outflow area. For much of the country, there are almost no satisfactory biological data with which to correlate hydrological data. The state-of-the-art was not readily available at the time of the initiation of this Assessment.*

However, to facilitate problem identification (a major objective of the Second Assessment), approximations of instream flow requirements were developed, based upon judgment and the best available information. These were termed instream flow approximations (IFA).** They were initially developed in the winter of 1974 and 1975 by a team of Fish and Wildlife Service biologists, using the USGS Water Supply Statistics*** and a variety of methodologies and references. Further refinements in the IFA data were made in 1977 due to further changes in the water supply data**** and to comments provided by regional sponsors and others.

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* Bayha, Keith D., 1976. Instream Flows--The Big Picture in Osborn and Allman (ed.) Proceedings of the Symposium and Specialty Conference on Instream Flow Needs, Vol. I, PP 95-121. Western Division of American Fisheries Society, Bethesda, Maryland.

** Instream Flow Approximations (IFA) are defined as flow regimes consisting of quantitative expressions of judgmental estimates of monthly flow at the outflow point(s) of an aggregated subregion, sufficient to support the habitat of aquatic life forms and outdoor recreation. The IFA prepared solely for use by the Water Resources Council as part of the Second Assessment.

*** The USGS Water Supply statistics for the Second National Water Assessment prepared in the fall of 1974 included depletions at near 1975 levels of development and also reflect operation of reservoir storage as it would have been detected by USGS discharge recording stations.

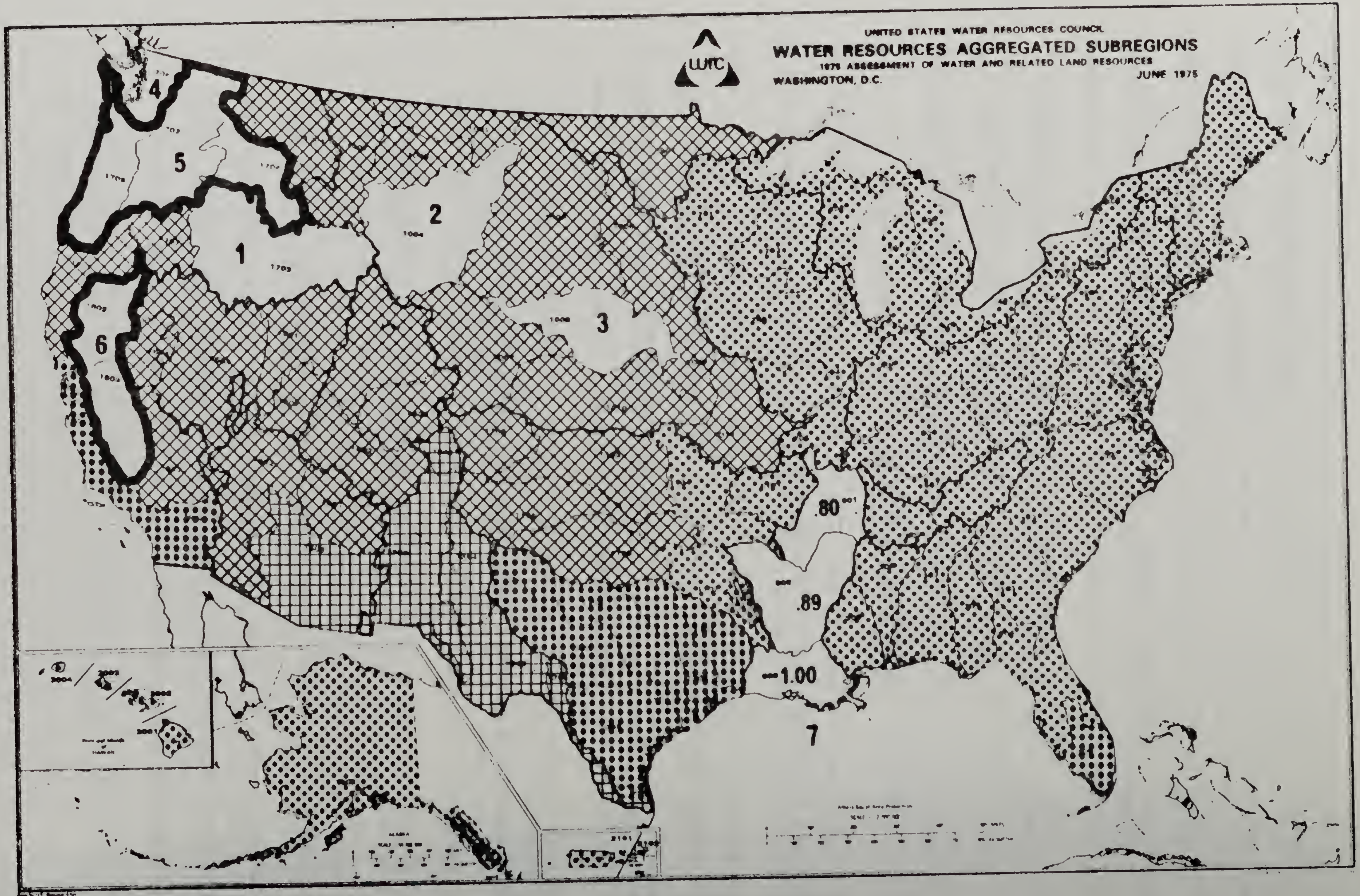
**** In response to comments by regional sponsors, some of the water supply data were adjusted as a result of comparative studies by the University of Texas in 1977.

The methods employed in arriving at the final instream flow approximations are varied reflecting the diverse combinations of factors considered. These include: nature of the ecosystem; relative water supply as influenced by hydrological conditions, storage, and man's past allocation of supplies; and availability of previous studies applicable for use in this Assessment (Figure III-30). The rational employed in various combinations of these factors is discussed in the Instream Flow Appendix. IFA data consist of annual (Table III-68) and 12 monthly figures for each of the 106 aggregated subregions (Table 19, Statistical Appendix).

- Special Problems in Riverine Ecosystems

The Alaska North Slope is a special case not reflected in this Assessment. This problem is due to winter withdrawals from beneath the frozen surface of the rivers of the artic slope. In winter, the streams in this severe environment consist of a chain of ice-locked pools. These pools are vital over a wintering habitat for river fishes and other organisms. The new petroleum industry taps these pools for industrial water needs to the detriment of aquatic life (Figure III-30).

Hydropeaking is projected to become a more significant factor in the water management of many river basins. Energy projections call for heavy reliance upon coal and nuclear fueled electrical generation. But there is also the assumption of a rise in the present trend toward


UNITED STATES WATER RESOURCES COUNCIL
WATER RESOURCES AGGREGATED SUBREGIONS
1975 ASSESSMENT OF WATER AND RELATED LAND RESOURCES
WASHINGTON, D.C.
JUNE 1975
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1703
1004
1008
1802
1804
1708
2101

Figure III-30

METHODS EMPLOYED IN ARRIVING AT INSTREAM FLOW
APPROXIMATIONS (IFA) BY AGGREGATED SUBREGIONS

NOTES FOR FIGURE III- 30 INSTREAM FLOW APPROXIMATIONS

The patterns on the map show where each of the following methods were used to obtain instream flow approximations (IFA). Except for method D below, IFA are based on water flow data prepared for the Second National Water Assessment.

⁘ A. Monthly IFA are 50 percent chance monthly streamflows. Annual IFA are averages of monthly IFA.

● B. Annual IFA are 50 percent chance annual streamflows. Monthly IFA are computed by multiplying the monthly 50 percent chance streamflows by the factor required to make the average of the monthly IFA equal the annual IFA.

▩ C. Monthly IFA are either 40, 60, or 100 percent of the estimated monthly natural flows depending on seasonal needs. Annual IFA are averages of monthly IFA. The estimated natural flows are obtained for this purpose by adding consumptive uses and exports to present average streamflows and subtracting imports and ground water mined.

▦ D. Method C above was used except that flushing flows (100%) were not included.

⬭ E. Methods for these locations are based on more detailed information available from the following references:

1. Bayha, Keith and Charles Koski (Editors), *Anatomy of a River: Report of Hells Canyon Controlled Flow Study Task Force,* Washington. 1974
2. *Reservation of Water in the Yellowstone River Basin,* Montana Fish and Game Commission. Helena, Montana. 1976
3. *Platte River Basin, Nebraska Level B Study,* Missouri River Basin Commission. Omaha, Nebraska. 1976
4. Puget Sound Task Force. *Puget Sound and Adjacent Waters, Comprehensive Water Resource Study.* Pacific Northwest River Basins Commission, Vancouver, Washington. 1970
5. Columbia Basin Fishery Technical Committee September 1975 letter report to Division Engineer, North Pacific Division, Corps of Engineers from Fred Cleaver, Program Director, National Marine Fisheries Service, Portland, Oregon.
6. Personal communication with Ed Whitsell, California Fish and Game Department, Stockton, California and Robert Hayden, Fish and Wildlife Service, Sacramento, CA. 1977
7. Interagency Ad Hoc Study Group. *Report on Mississippi River Flow Requirements for Estuarine Use in Coastal Louisiana and the Atchafalaya Basin.* Mississippi River Commission, Vicksburg, Mississippi. 1970. IFA for ASR 801 and 802 are obtained from the IFA for ASR 803 using the ratio of streamflow from ASR 801 and 802 to the streamflow from ASR 803.

peaking operations of the Nation's hydropower facilities. Such operations place an extra burden on stream ecosystems. Violently fluctuating streamflows tend to flush the fine sediments downstream, resulting in loss of beaches and spawning gravels. These sediments are not replaced by recruitment from upstream due to their entrapment in the reservoir basins. The result is a vastly different stream ecosystem in the reach below the dam. In the Pacific Northwest the effects of greater peaking of that region's substantial hydropower facilities upon the salmon and steelhead populations is the subject of a current study.

Stream Alteration for a variety of purposes is a widespread problem for fish and wildlife populations. Manipulation of rivers and streams through structural developments such as dams, levees, dredging, and channelization have been the traditional approaches to solving water management problems in the United States. Stream channelization for flood control and drainage results in removal of the riparian habitat and disturbance of the character of the stream bed itself. Studies have shown that channelization totally destroys the stream ecosystem for a substantial period, in some cases for decades. In the past decade greater public awareness of the ecological consequences of reliance upon such activities has led to a shift toward non-structural solutions. This trend, reflected in the flood damage projections of this Assessment, will benefit fish and wildlife populations. Such programs offer exceptional opportunities for complementary greenway development and recreational uses. Preservation of remaining natural stream systems is gaining momentum, stimulating demand for better inventory data and analytical techniques for assessing values of riverine ecosystems.

Riparian habitats are very susceptible to damage from over grazing by livestock. Removal of the understory in forest cover is of special concern particularly in the southwest where this habitat is vital to the native fauna. When riparian lands are grazed, stream channels tend to become wider, shallower, and warmer. These physical changes adversely affect the aquatic organisms. Fencing of streams and riparian zones has been demonstrated to be useful in reversing this effect.

Water quality is of vital importance to fish and wildlife resources. While the quality of the Nation's streams is reportedly improving, non-point source pollution (primarily in the form of contaminants carried by surface runoff from agricultural lands, urban developments, and sites disturbed by logging operations and construction) continues to be of major concern. These pollutants contaminate the aquatic environment as well as water supplies of downstream communities and industry and eventually the estuarine ecosystems. Control of non-point source pollution remains a severe problem throughout most of the Nation and is essential to maintaining wildlife habitat.

Water quality standards are an essential part of any State water quality management system because they serve as a basis for establishing instream flow requirements and controlling the introduction of toxic substances, as well as judging other water quality programs. The chemical and biological parameters needed to establish State water quality standards for the protection and propagation of fish, wildlife, and recreation in and on the Nation's waters have been well studied. It is becoming evident that in addition, the physical properties of streams such as depth, velocity, turbidity and temperatures must be included in state water quality standards if the Nation's waters can support the propagation and maintenance of fish, wildlife, and recreation.

Ground Water/Surface Water Relationships are both insufficiently understood and poorly documented. Failure to manage use of ground water and surface water resources as one water supply has led to substantial problems in certain areas (i.e., subsidence in Texas, Louisiana, and Florida; degraded riverine habitat in Nebraska, California, and Arizona). Changes in both the research and data collection programs and in our institutions and laws are urgently needed.

- Legal and Institutional Relationships

These problems indicate that future options are basically twofold: (1) take limited action and witness the collapse of the ecological balance of our riverine ecosystem with economic and social impacts; or (2) do something on a major scale to alter the trends and mitigate the adverse impacts.

The search for the proper course of action is what planning is all about. While technical expertise can offer new practices, processes, and strategies, ultimately there must be revision of those legal and institutional mechanisms which have failed to keep pace with the Nation's growth.

Perhaps chief among these are western water law--and the economics of pricing water from water resource projects. These topics and others are discussed in Part IV of this report.

etlands and Coastal Ecosystems

Wetlands are lands where water is the dominant factor determining the nature of soil development and the types of plant and animal communities living at the surface. It spans a continuum of environments where terrestrial and aquatic systems integrate. *

A coastal ecosystem or estuarine zone is ". . . an environmental system consisting of an estuary and those transitional areas which are consistently influenced or affected by water from an estuary such as, but not limited to, salt marshes, coastal and inter-tidal areas, bays, harbors, lagoons, inshore waters, and channels, and the term 'estuary' means all or part of the mouth of a navigable or interstate river or

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* Cowardin, Lewis M., Virginia Carter, Francis C. Golet, and Edward T. LaRoe, 1977. Classification of Wetlands and Aquatic Habitat for the United States. U.S. Fish and Wildlife Service. April 1977.

stream or other body of water having unimpaired natural connections with open sea and within which the sea water is measurably diluted with fresh water deriver from land drainage. **

Although there are obviously some overlaps in these definitions, there are also some unique aspects. They are considered in tandem here primarily because man's institutions as they presently exist relate similarly to both.

- Wetlands

During the two centuries of this Nation's existence our national heritage of wetlands has decreased from approximately 120 million acres to about 70 million acres. There are no nationally consistent data describing the location and type of these remaining wetlands; however, the Fish and Wildlife Service is currently conducting a National Wetlands Inventory. The Inventory has been designed to provide a single, hierarchial system of classification and storage of information which will describe all wetlands on an individual and cumulative basis in terms of their ecological and physical characteristics, geographic location, and natural resource values. A data base is being established in both map and computer file form. This will permit compilation, storage, and retrieval of the data. The Inventory is scheduled for completion in 1979 and will be kept current thereafter.

** Federal Water Pollution Control Act Amendments of 1972. (P.L. 92-500, 33 U.S.C. 1155.)

Wetlands not only provide habitat for waterfowl and other wildlife, breeding grounds for fish, and recreational activities, but they also act as natural filters, absorbing pollutants and recycling nutrients, as a buffer for extreme events such as floods and storm tides, and frequently play an important role in recharging ground water aquifers. Research has demonstrated that wetland ecosystems possess values to society far greater than generally perceived.

Conversion of prairie grasslands and associated wetlands to cropland through private action and Federal programs has been devastating to North American waterfowl and other prairie wildlife. Until the President's Executive Order of May 24, 1977, drainage had been promoted by some Federal programs in direct opposition to other Federal programs aimed at preserving waterfowl habitat. Draining of bottomland hardwood forests to provide additional agricultural production has also adversely affects these natural ecosystems. Furthermore, dredging and filling of coastal wetlands for real estate development have resulted in substantial losses.

- Coastal Ecosystems

Abutting the approximately 90,000 miles of shoreline and within the United States, a wide spectrum of habitats and coastal types is found. These include such diverse areas as the ice-stressed systems of arctic Alaska, the coral reefs and mangrove swamps of the Gulf of Mexico, Caribbean, and Hawaii, as well as the rocky shores of New England and the Pacific Coast and the extensive salt marshes of the mid and south Atlantic and the Gulf Coast.

An overview study of the estuaries of the Nation was completed under contract by the Virginia Institute of Marine Science (Appendix 14). It describes existing estuaries in the country, their significance, the threats and conflicts which they face, and the management needs for the future.

Concern for estuarine and nearshore marine areas is appropriate. In recent years, economic returns from estuarine and nearshore marine areas have reached $490 million ex-vessel commercial fisheries landings (1972); $160 million expenditures for sportfishing (1970); $224 million expenditures for waterfowl hunting (1970); and $5.7 million in fur harvests (1970). Other uses of estuarine and nearshore marine areas such as recreational boating, bird watching, and swimming are also heavily dependent upon the quality of the water and water-related resources. Within these diverse ecological systems (the characteristics of which are largely determined by such major natural factors as geological history, tidal amplitude, weather, currents, and latitude) the impacts of man have become a major force for alteration of water and water-related resources.

Alteration of our coastal ecosystems has accelerated since World War II, through the practice of dredging and filling estuarine waters to produce high-valued land for construction of buildings and other works of man. Already, 75 percent of the Nation's estuaries have been severely degraded by dredging, filling, or pollution. This loss of coastal ecosystem habitat has, in some areas, crippled estuarine and nearshore marine fishery resources through loss of the vital nursery areas. Human population growth in the coastal zone is three times greater than the national average.

Upstream flow depletions and dredging of navigation waterways in the coastal zone changes the flow of fresh water and tidal salt water, upsetting the circulation patterns of the estuarine community. This in turn affects distribution of vegetative habitat and dependent animal populations.

Reduction of freshwater flows into an estuary can affect the estuary in a number of ways: increased salinity, increased flushing time, change in circulation, and decreased sedimentation. All definitions of an estuary include mixing of sea water with fresh water, but the amount of fresh water in proportion to the size of the estuary varies enormously, not only from one estuary to another, but also seasonally within a single estuary. The biota found within an estuary reflect the relative stability or instability of the salinity regime existing there, and any change in the freshwater input will likewise affect the salinity regime and the biotic communities. Within the lower reaches of a river or in a bay or sound, salinity is a continuum, diminishing upstream and increasing toward the sea. The continuum is dynamic, however, in that it fluctuates in response to tidal influence, weather conditions, and freshwater discharge. A decrease in discharge moves the isohalines further upstream. Significantly, the lowest diversity of organisms is found in the transition zone between salt and fresh water where salinity fluctuates most widely.

Probably the most significant effect caused by reduction of freshwater flows is the change of salinity and its resulting effect on fish and wildlife habitats. In tidal rivers, such as the Potomac, a reduction of freshwater flow has the same effect as low flow conditions in the summer months; it moves the isohalines upstream but on a permanent basis. Fauna requiring a particular range of salinities reestablish themselves further upstream. Existing oyster beds are subjected to higher salinities, and those in the lower reaches may be subjected to predators such as the oyster drill and the probability of infectious oyster diseases such as MSX, which are salinity-limited under normal conditions. New oyster rocks and cultch would have to be established further upstream in order for the larval oyster set to remain viable. Normal spawning and nursery areas for anadromous fish such as herring and shad might be reduced in size. This might be significant if suitable bottoms were not available or if a physical barrier to upstream migration were present. In cases such as the Potomac, the size and salinity of the receiving body of water (the Chesapeake Bay) determine the extent of salinity change in the river caused by a reduction in freshwater flow. The Texas-Gulf coast and south coastal California are examples of estuaries deprived of substantial freshwater inflow which consequently are of high salinity, as discussed later.

The damming of rivers and reductions in flow reduce the amount of sediment reaching the estuaries. The sediments themselves are important in controlling the ecosystem, as they are sites for the sorption of nutrients and for microbial activity responsible for the decomposition of organic matter. In some cases, this can be an advantage, particularly where navigation channels must be maintained. In other cases where large flows are prevalent, deltas depend upon this continued nourishment by sediments. Without the sediment load and coastwise dispersion, erosion takes place with the loss of beaches and the deltas themselves. In the latter case, a change of wildlife habitat results.

Impacts of projected water use and supply for years 1985 and 2000 on estuarine and nearshore marine environments and resources cannot be adequately assessed on a regional basis due to the differing demands on aggregated subregions within the same region which have a tendency to minimize impacts when water demands are aggregated. When individual ASRs are examined, however, certain regions appear to face significant impacts. The estuaries which might receive the highest impacts because of changes (principally increases in water use) include:

Texas-Gulf Coast--In this region, if predicted increases in consumptive water use are realized, changes in salinity regimes of estuarine areas could result in serious impacts to nursery areas and fishery habitats. The Laguna Madre and Baffin Bay are examples of shallow estuaries where evaporation in this arid climate has exceeded freshwater inflow resulting in hypersaline conditions. Further east the Nueces River feeds Corpus Christi Bay and the Guadalupe and San Antonio Rivers empty into San Antonio Bay. Connections with the Gulf of Mexico are quite restricted; therefore, reduction of flow would undoubtedly increase the salinity of the extensive bay system. The Colorado and Brazos Rivers empty directly to the Gulf of Mexico, but the Trinity and San Jacinto Rivers feed the extensive Galveston Bay complex. Again, passes through the barrier islands are limited, and reduction of flow would increase the salinity from the present average of about 12 ppt. A significant increase could seriously affect the shrimp and shellfish industries, and valuable nursery areas could be lost.

Louisiana Coast--Leveeing of the Mississippi River has altered the distribution of silt laden fresh water to such an extent that the coastline is subsiding rapidly. The land mass of coastal Louisiana is being reduced at a rate of 16 square miles per year. Salt water intrusion is dramatically altering the fresh water and brackish marshes.

Southern Florida--Diversion of fresh water supplies, formerly supplying the Everglades by the cross Florida navigation system through Lake Okeechobee, has reduced the size of the Everglades and the estuarine ecosystem off south Florida and increased the adverse impact of normal droughts.

San Francisco Bay - Sacramento Delta--Massive diversions of Sacramento River flows through the delta to supply southern California have transformed San Francisco Bay from an estuarine to a marine environment and jeopardize the substantial anadramous fish and waterfowl values of central California. A major challenge faces planners in these areas as they seek to reallocate available supplies in an effort to preserve the productivity of these ecosystems. Detailed, area-related analysis must be made on each estuarine area threatened with water supply modifications before accurate assessments of the impacts of these changes can be made.

Although estuarine systems are adapted to widely fluctuating natural flow conditions, long term alterations of an area's water supply (be it increased or decreased) may have marked effects both on the resources present and on the ability of the system to rebound to its normal condition. Within each coastal region of the United States, one of the major concerns is pollution. In some areas, such as southwest Florida and California, the major sources of pollution may be domestic waste, while in other regions, such as New England and the Pacific Northwest and Alaska, industrial pollution may be the major concern.

Although the assumption has been made that the 1983 water quality goals will be met by 1985, it should be noted that the flushing of estuaries is partly a function of fresh water flow, and a reduction of flow would tend to increase the concentration of pollutants within the estuaries unless they can be reduced at the source. Since the Texas bays have a tidal range of only about 0.5 feet, the flushing characteristics must be considered along with fresh water input.

Though not an estuarine or nearshore environment of the coastal United States, the Gulf of California is a region that might also face similar problems. Water use projections for the Lower Colorado Region (ASR 1502) and the Rio Grande Region (ASA 130R) are similar to those in some of the Texas-Gulf ASRs. Further United States water demands in these regions may impact these international waters.

- Legal and Institutional Ramifications

Management responsibility for estuarine and nearshore marine areas is shared by a multiplicity of Federal, interstate, State, and local agencies. Recent Federal initiatives, particularly the Coastal Zone Management Act of 1972 and the 1972 Federal Water Pollution Control Act Amendments, are encouraging or mandating coordination of environmental considerations of various agency actions at the several levels (See Part IV).

At the State level, it is not likely that agencies will be created within the states' organizational frameworks to function solely or exclusively as the managers of the states' estuarine or nearshore marine areas, but the awareness of the need for closer visible coordination and cooperation between agencies is increasing.

Although there is general national concern for water quality with regard to the status of the Nation's estuaries in the next 10 to 25 years, if water quality goals presently mandated by Federal legislation are realized over the next few decades, and responsible local, state, and Federal managers are provided support for necessary restrictions on conflicting, non-compatible uses, the people of the Nation can look forward to continued, aesthetic, recreational, and economic return from the Nation's coastal ecosystems.

Upland Ecosystems

Uplands are lands not classified as wetlands, streams, lakes, estuaries, or ponds. Upland ecosystems encompass prime wildlife habitat, as well as areas almost totally devoted to man's intensive uses. Man's ability to alter the face of the earth has developed to the point that change is occurring faster than organisms and communities can adjust. There is no display of the degree to which all uses collectively have altered the natural ecotypes described by Bailey.* However, it is known that some ecotypes, such as prairie grasslands and bottomland hardwoods, are rapidly being reduced by expansion of agriculture, strip-mining, and urban-industrial encroachment.

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* Bailey, R.C. 1976. Ecoregions of the United States (Map). USDA Forest Service, Ogden, Utah, scale 1:7,500,000.

The commercial value of uplands is high, as demonstrated by the accelerating land values. The value of the native vegetative communities, which support most of our wildlife population, is somewhat less obvious. While conversion of native communities to the specialized uses of man is no doubt meritorious to a degree, there is a point beyond which loss of the gene pools of certain species of flora and fauna cannot be prevented. Fish and wildlife populations are at the mercy of change in land use. Other chapters in this document describe the expected trends in expansion of agriculture, mining, and urban needs. The effects of such land use changes upon fish and wildlife populations will be significant.

- Agriculture

Development of agricultural land has both positive and negative effects on fish and wildlife. The trend toward clean farming, increased field size, new land development through drainage and irrigation, and the application of massive amounts of pesticides and fertilizers have a tendency to produce a mono-culture in the vegetative cover of our landscape. This mono-culture is of far less value to wildlife populations than is the traditional form of agriculture which left hedgerows, roadside areas, and small untilled areas in and around the fields where agriculture was less productive. These areas provided the vital mix of habitat types upon which wildlife populations depend.

Recently the high price of soybeans has stimulated the clearing of bottomland hardwoods in the Lower Mississippi Valley and in the southeastern coastal States. This conversion of one vegetative cover type to another has a serious negative effect when one realizes that the bottomland hardwood cover type is rapidly disappearing from the face of the earth. Similar changes were observed in the prairie States when the price of wheat accelerated following large sales to the communist block nations. Drainage of wetlands in the prairie-pothole country of Minnesota and the Dakotas and in the coastal zone of the southeastern United States poses a significant threat to the wetland associated wildlife populations.

- Grazing

Overuse by domestic livestock has damaged a considerable portion of our western rangelands. The U.S. Forest Service has estimated that 15.3 million acres are in "low ecological condition," in need of restoration.* The trend toward better management of our public rangelands will improve habitat for wildlife as well as livestock. However, special emphasis is needed in protecting riparian habitats from overgrazing, especially in the arid Southwest.

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* U.S. Forest Service, 1975. Draft Environmental Impact Statement-Renewable Resource Program, 1977-2000.

- Strip-mining

We hear much talk of strip-mining coal and developing oil shall resources in the western United States:

> The surface mining of coal causes extensive direct and indirect damage to wildlife. The direct impact is the distribution or displacement of all species from the areas of excavation. The more sedentary species such as reptiles, rodents, etc. may be directly destroyed while more mobile species such as game animals, birds, predators, etc. will leave the area.
>
> The impairment of wildlife habitat will extend a considerable distance beyond the immediate areas of excavation and coal processing. Many animal species are quite sensitive to the activity of men and machines and move far enough away so that their presence is not felt. Again, this is a problem of competition for "living space."
>
> Impairment of critical habitats, if not carefully controlled, can magnify greatly the damage done to wildlife. A classical example is the effect of elimination of winter range for big game animals. The controlling factor in big game populations in most regions is the availability of winter range. A mining operation (even a modest one) could destroy the big game population of the area, even though many square miles of good forage may exist in milder seasons and remain untouched. An even greater magnification in impact can take place if the displaced animals move into an adjacent area which is stocked to carrying capacity. Overgrazing of this area will result in lowered carrying capacity and potentially greater losses to the population.

A second major impact of surface mining in the degradation of aquatic habitats in the area and downstream of the excavations.* The use of the watershed or catchment basin for energy develop ment may affect stream ecology through changes in runoff pattern, changes in silt load, changes in temperature regime, chemical enrichment, or toxic pollution.

"The physical removal of the climax vegetation through the action of strip mining, road construction, and town building is likely to alter the runoff pattern greatly. Of particular importance in the arid West are the resulting changes in the silt load brought to the stream channel and the direct effects of stream turbidities, as well as the resulting change in flow regime upsetting the equilibrium between scour and deposition."*

In the immediate area of the mine, surface and subsurface hydrology are severely disrupted. Stream channels and flood washes are rearranged to accommodate the mining operation. Interruption of ground water movement results in water accumulation in the mine area which must be pumped out and into the drainage system. The quality of this water will most probably be poor, possibly containing high concentrations of trace elements and may be either acidic or alkaline depending on the composition of the surrounding soils. Drainage water which leach through mine spoils will also have these same water quality problems. Erosion of spoil piles is likely to result in significant sediment loads downstream in the drainage area of the mining site.

Spaulding and Ogden, 1968, indicate that in Kentucky, stream sediment loads increased by three orders of magnitude as a direct result of strip mining. Approximately one acre-foot of sediment is produced annually for every 80 acres of disturbed land.

The effects of silt and sediment on aquatic wildlife include direct fish kills, burial of spawning beds of trout and salmon, reduction of aquatic organism production, reduction in light transmittance, alteration of temperature gradients, filling in of pools, and alteration of flow patterns. These changes listed above can significantly alter habitats such that desirable species are either seriously reduced in number or eliminated entirely. At the same time conditions may be made favorable for undesirable species.

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* U.S. Fish and Wildlife Service, 1976. Coal Project: Background Information (Planning and Management). FWS/OBS 76/8) July 1976. P. 49. Washington, D.C.

* Stalnaker, Clair B., 1977. Abstraction, Appropriation, and Instream Flow Needs. Fisheries. Vol. 2, No. 1, pp 17-19.

> The presence of toxic waste materials in runoff waters can affect wildlife by causing direct loss of certain species if concentrations are great. Lesser concentrations can suppress productivity, growth rate, and reproduction of many aquatic species. The duration of toxic waste pollution can be long term. In Appalachia it is estimated that the time to completely leach out toxic material in spoil piles ranges from 800 to 3000 years (Spaulding and Ogden, 1968).
>
> In hilly or mountainous areas strip mining can often result in the creation of vertical highwalls as high as 200 feet. This results from the stripping of the overburden from a slope to gain access to a horizontal coal seam. The stripping usually proceeds until it is uneconomic to strip more over burden or until a property line or lease limit is reached. The impact and final shape of a highwall is similar to that of a highway cut and they may form a dangerous barrier to the passage of wild animals. In the past, uncontrolled operations resulted in highwalls which circumscribed entire mountains, isolating the area above the highwall completely.*

The attendant human activity that results from development places added burdens upon both fish and wildlife populations and man. Substantial study of such changes is needed to help guide man's decisions so that the adverse impacts upon fish and wildlife can be neutralized.

- Environmental Contaminants

Pollutants from varied sources (agricultural chemicals, industrial and municipal effluents, heavy metals, and oil spills) present a threat to the local habitat of fish, wildlife, and man, but collectively represent a national and global threat as well.

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* U.S. Fish and Wildlife Service, 1976. Coal Project: Background Information (Planning and Management). FWS/OBS 76/8) July 1976. P. 49. Washington, D.C.

"The effects of this constant and increasing contamination of the air and oceans are already apparent. Some wild species have declined dramatically. The brown pelican has all but disappeared as a breeding species on much of the Pacific Coast and around the Gulf of Mexico. There has been a sharp decline in the nesting success and numbers of bald eagles and ospreys in the eastern United States. All of these birds feed heavily on fish, which absorb the persistent pesticides and store them in their tissues. DDT is considered a major culprit in the decline of these birds, as it is in the virtual extinction of the peregrine falcon in eastern North America.

"A chilling threat--not only to wildlife but to all life is seen by some scientists today in the cumulative effects of pollution on the oceans. Marine phytoplankton are the bases of food chains in the seas. Without these microscopic plants, all ocean life from the smallest shrimp to the largest whales would perish. Moreover, phytoplankton have approximately three times as much gross capacity for converting carbon dioxide to usable oxygen as all land plants combined. Their present abundance is essential, these scientists believe, to maintain the oxygen content of the atmosphere at a level that will support life."

"But phytoplankton are extremely intolerant of acidity and trace elements, which are common in most pollutants, including pesticides. When carbon dioxide--a near universal byproduct of human activity--is absorbed by sea water in quantities beyond those which marine plants can readily convert to oxygen, it creates an acid condition that kills the phytoplankton. Trace elements in other pollutants cause the death of more. If too many die, according to this sobering theory, the oxygen content of the atmosphere will fall, and Earth will become another dead planet. How far down the line the world has progressed toward this grim end, no one is sure. But the rising quantities of carbon dioxide in the atmosphere and the fact that DDT has been found in the tissues of Arctic polar bears, Antarctic penguins, and many wild species between the poles are warnings of a possible trend in that direction."

"The trend can be reversed, if Americans and people of other nations have the will, intelligence, and prudence to act promptly and vigorously to cure the Earth's environmental ills. Wildlife that is threatened by air and water pollution and by the destruction of essential vegetation, soil erosion, and a general degradation of the environment can be saved. _By saving wildlife, man may save himself_."*

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* Wildlife Management Institute, _Wildlife--The Environmental Barometer_, Washington, D.C.

Comparison of National and State-Regional Futures

There is considerable variation in acceptance of instream flow estimates for fish and wildlife by the regions. Some regions did not account for instream flows for fish and wildlife because these flows do not have recognized beneficial uses. The values in the State-Regional Future vary considerably from region to region.

Water Requirements for Fish Hatcheries

Fish hatcheries, both state and Federal, are an important aspect of maintaining the Nation's supply of fishing for recreational purposes. These stocking programs also provide substantial commercial and agricultural production of market fish.

Federal fish hatcheries (an offstream use) withdrew about 628 million gallons of water per day in 1975 (Table III-69). These withdrawals are expected to increase only by about 15 percent by 2000. Freshwater withdrawals for fish hatcheries constitute only 0.2 percent of the total withdrawals.

The Pacific Northwest Region accounts for 43 percent of Nation's total diversions for fish hatcheries. The ten regions west of the Upper and Lower Mississippi Regions withdraw about 75 percent of the Nation's total water requirements for fish hatcheries. Withdrawals for fish

Table III-69

Summary of Withdrawals*
in National Fish Hatcheries by Region - 1975, 1985, 2000
(Million Gallons Per Day)

Region	Withdrawals 1975	Withdrawals 1985	Withdrawals 2000
New England	37	55	55
Mid-Atlantic	21	21	21
South Atlantic-Gulf	18	18	18
Great Lakes	22	26	28
Ohio	36	45	46
Tennessee	15	15	15
Upper Mississippi	5	6	6
Lower Mississippi	1	1	1
Souris-Red-Rainy	3	3	3
Missouri	47	48	48
Arkansas-White-Red	43	46	48
Texas-Gulf	17	11	11
Rio Grande	7	9	11
Upper Colorado	20	27	34
Lower Colorado	22	22	23
Great Basin	2	3	3
Pacific Northwest	272	301	314
California	41	41	41
Alaska	0	0	0
Hawaii	0	0	0
Caribbean	0	0	0
Total, Regions 1-18	628	697	725
Total, Regions 1-21	628	697	725

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* Consumption by hatcheries is negligible.

hatcheries are not expected to present a major regional water supply problem between 1975 and 2000 but isolated areas in the West may encounter periodic supply problems. The larger problems will be those of maintaining adequate streamflow of the necessary qualities to fully utilize the fish stocks produced in the hatcheries, especially for recreational fishing.

PART III

CHAPTER 11

WATER REQUIREMENTS ASSOCIATED WITH NATURAL AREAS, HISTORIC RESOURCES, AND WILDERNESS AREAS

Preservation of certain natural areas requires maintenance of surface water flows, ground water levels, and natural high water quality. Disruptions to any of these natural conditions may adversely affect natural areas and their related aesthetic qualities. Generally, no irretrievable commitments of water resources are made in natural areas. Where protected natural areas are situated at the headwaters of a river or stream (for example, Yellowstone National Park) downstream users are virtually assured of continued high water quality as well as quantity. However, where natural areas are located downstream precautions must be taken upstream to ensure the water quantity and quality necessary for the continued well-being of the natural area.

Preservation of the functional and aesthetic integrity of some historic resources is dependent on maintaining water conditions as they appeared during the time of the historic event or period represented. Examples are the Chesapeake and Ohio Canal, the battlefield near the Concord River in Minuteman National Historical Park, and the Arkansas

River adjacent to Bent's Old Fort National Historic Site in Colorado. Water also contributes to the aesthetic setting of some historic properties (historic docks, lighthouses, locks, dams, and waterfront districts) and to the operation of others (mills and boatyards). Seldom does the use of water for these purposes conflict with other water uses.

Occasionally, water projects aid in historic preservation. For example a well planned flood damage reduction program is imperative for protecting historic areas, especially since these are irreplaceable resources. But problems and conflicts can arise when plans for reservoirs, canals and pipelines, stream channelization, agricultural operations, and private land developments are undertaken in areas containing historic resources. Natural areas and historic resources are issues in planning for water resources development because projects may adversely affect biotic communities or conflict with preservation. Consequently, there is a need in water resource assessment and planning to balance national economic development with environmental quality considerations such as preservation of natural areas and historic resources. The direct offstream water requirements for natural areas and historic resources are quite small. The critical water requirements are those instream uses which enhance or support the natural and historic areas and associated ecosystems in their natural or historic relationships.

Natural Areas

Water resource development projects adversely affect existing biotic communities. Depending upon the nature of the project the effects range from near total destruction to only minor damage. Construction of reservoirs results in submergence of geological features and destruction of existing terrestrial and aquatic ecosystems. Reservoirs having widely fluctuating water levels can produce unsightly and biologically unproductive mudflats. Reservoirs constructed upstream from natural areas and utilized for diversion of water resources may reduce surface water flow and ground water levels downstream resulting in negative impacts on biotic communities. Everglades National Park is an example of an area impacted by the construction of canals and levees upstream of the park that have reduced the natural southward flow of freshwater from Lake Okeechobee into the park threatening some of the park's unique flora and fauna with extinction.

Natural areas are particularly sensitive to water development projects for increasing agricultural production. Pastures and croplands often are created by either draining wetlands or by introducing irrigation water. In either case natural ecosystems are destroyed or damaged. Some sources of irrigation water may adversely impact an aquatic environment far removed from the irrigation. If ground water is used for irrigation the resulting lower water tables could produce serious impacts on natural areas and their associated species.

Energy production conflicts with natural area preservation in many ways. It could involve adverse effects associated with reservoir construction for generation of hydroelectric power; attendant effects from coal-fired power plants (including discharge of heated water and other pollutants into the aquatic environment and production of stack emissions harmful to plants); construction of electric transmission lines; and a multitude of other effects resulting from industrial, commercial, and residential growth. Mining for coal and other minerals frequently destroys riparian areas and their associated ecosystems. Acid drainage from abandoned mines has polluted the waters of may rivers and streams making them productive as a natural area.

Use of water resources for recreational purposes and for maintaining fish and wildlife populations occasionally conflict with natural area preservation. Natural shorelines and back-up land areas are drastically modified to provide large concentrations of people with opportunities for swimming, boating, and other recreational pursuits. Likewise, natural areas may be modified with dikes, fences, irrigation systems, and farming programs to maximize production of wildlife foods or improve habitat for specific species of wildlife.

Efforts to reduce flood damages or provide navigation by constructing impoundments and levees and by dredging and stream channelization often have disastrous effects on biotic communities. However, nonstructural solutions foster retention of natural conditions and preservation of natural diversity.

Historic Resources

Conflicts between water resource development and historic preservation are aggravated by the fact that prehistoric and historic communities were concentrated along water courses and in proximity to flood plains and other arable lands. As a result historic resources and needs for present-day water resource development frequently are concentrated in the same places.

Reservoirs can inundate historic resources. Secondary effects result from recreation uses of reservoirs when visitors collect artifacts and vandalize sites and structures around the reservoir. Archeological and architectural salvage programs mitigate some of these problems, but seldom are they of sufficient scope to prevent or mitigate damages sufficient to retain authenticity.

Agricultural operations are among the primary destroyers of historic and prehistoric sites. Water resource development for agriculture stimulates expansion or intensification of agriculture, destruction of archeological sites almost inevitably occurs. Land-leveling, subsoiling, and channelizing irrigation water are particularly destructive and without any effective programs or methods to reduce damages or provide for mitigation when these damages occur.

Private and public development of land dependent on the availability of water has complex direct effects on historic resources. Urban renewal can result in the destruction of historic buildings and structures; suburban development of open land destroys archeological sites; construction of sewers, roads, streets, highways, power generation, and transmission facilities, and other support systems necessary for such growth destroy both prehistoric and historic sites and structures.

Because most major water resource projects either take place on Federal land or involve Federal funding or licensing the provisions of Federal historic preservation laws are applicable. When should historic surveys be accomplished? Who has the responsibility to do historic survey? The U. S. Environmental Protection Agency funds preservation or salvage of historic properties within the rights-of-way of sewer projects, but it relies upon local jurisdictions to identify and mitigate the secondary effects of such projects (for example, when urban growth and development have adverse effects on historic resources). Often, however, the local jurisdication has no policy whatever for historic preservation.

The U.S. Army Corps of Engineers tends to require the identification and protection of historic properties by permit applicants only when there is definite information indicating that the applicant's project will threaten such property. But, because many historic properties have not yet been identified, such information is usually not available.

A further complication is that State and local provisions for historic preservation may conflict with or crosscut Federal regulations. Some local jurisdictions, for example, have protective ordinances applying only to prehistoric archeological sites, historic buildings, landmark buildings, historic districts, or Indian burial sites. It is easy for a project planner to confuse compliance with a local ordinance or State law with compliance with Federal law, or vice-versa. The comprehensive nature of Federal concern for historic preservation may conflict with more limited preservation interests held by local communities. On the other hand, the specific interests of local communities in preserving their important properties may be poorly identified through the Federal process.

Programs For Natural and Historic Resources Preservation

National programs for preservation of natural areas have been developing in an uncoordinated and fragmented fashion. In recent years, the Federal Government, in response to increasing concerns for protection of environmental quality, has enacted a number of laws dealing with natural area preservation. The Wilderness Act (P.L. 88-577) was passed in 1964; the Wild and Scenic Rivers Act (P.L. 90-542) in 1968; the National Environmental Policy Act (P.L. 91-190) in 1969; the Marine Protection, Research, and Sanctuaries Act (P.L. 92-532) in 1972; the Coastal Zone Management, Act (P.L. 92-583) in 1972; amendments to the

Federal Water Pollution Control Act (P.L. 92-500) in 1972; the Endangered Species Act (P.L. 93-205) in 1973; and amendments to the Land and Water Conservation Fund Act of 1965 (P.L. 94-422) in 1976.

States administer a variety of programs for protection of natural resources on their lands. For example, state parks, monuments, preserves, wildlife refuges, reservations, forests, estuarine sanctuaries, and wild and scenic rivers. They also have statewide progrmas such as forest fire protection and assist local governmental units in natural resource protection, frequently through participation in cooperative programs with the Federal Government. States conduct or participate in river basin studies, make state water plans using Title III and other grant programs, coordinate preparation of coastal zone management programs, and prepare comprehensive State outdoor recreation plans that recognize the need for natural area preservation. A survey in 1972 by the U.S. Department of the Interior, Bureau of Outdoor Recreation indicated that local governments were protecting about 1.7 million acres of wilderness, primitive, and natural areas.

Some of the Nation's choice natural areas are being preserved by industries and privately financed citizen organizations. The Nature Conservancy is an outstanding example of such an organization. Its goal is to preserve ecological diversity through protection of significant natural lands. It acquires lands both for later transfer to governmental units and for its own stewardship. It has acquired and transferred to appropriate governmental units and private organizations about 390 natural areas containing 900,000 acres. In 1977 it owned and managed some 660 preserves having 400,000 acres. The National Audubon Society is another leading conservation organization administering natural areas. In 1977 it had 67 wildlife sanctuaries with some 180,000 acres.

National program for preservation of historic (archeological, historic, and architectural) resources was established by the National Historic Preservation Act of 1966. The act provided for establishment of the National Register of Historic Places, under the Secretary of the Interior, to foster preservation of districts, sites, buildings, structures, and objects significant in American history, architecture, archeology, and culture.

The Federal Government administers programs to preserve historic resources in Federal ownership. At the end of 1976 the National Park System contained 170 historical areas having about 1/2 million acres. Historic resources on lands adminstered by the Bureau of Land Management are protected in designated "Important Cultural Sites" and in the National Forest System.

State Historic Preservation Officers conduct statewide comprehensive surveys and develop historic preservation plans under the authority of the National Historic Preservation Act. The States administer a variety of programs for protection of historic resources on their lands and they also assist local governmental units in historic resources protection. The States also administer the historic preservation grants program for eligible projects within their borders.

Local governments undertake local historic preservation planning and projects. They also regulate activities of the private sector through local preservation and environmental ordinances and regulations. According to the Department of the Interior's 1972 survey local governmental units were protecting 22,000 acres containing historic resources.

Privately financed citizen organizations play a major role in preservation of historic resources throughout the Nation. They are organized at national, state, regional, and local levels to preserve single properties, groups of properties, and historic districts. The National Trust for Historic Preservation and the many State and local historical societies do outstanding work in preserving historic resources. State and local archeological societies work for the identification, study, and protection of historic and prehistoric sites and exercise control over the quality of archeological excavations. Professional organizations such as the Society of Professional Archeologists are active throughout the Nation.

Opportunities for Preservation

As the population of our Nation continues to grow so will the demand to preserve natural and historic resources. In view of the rapid rate of land development, water resource development, and other factors the Nation must substantially increase efforts to identify and preserve in perpetuity units of land and water representing a full array of biotic communities, geologic features, and other components of the Nation's natural heritage.

In future studies there may be opportunities to identify and acquire lands that have been damaged by erosion, stripped by surface mining, cluttered with abandoned and obsolete industrial and commercial facilities, or otherwise scarred by man but which may be preserved for natural and historic purposes.

The variety of legislated programs, the lack of coordination, and the broad Federal involvement make it difficult to comprehend the scope of natural area preservation throughout the Nation and the subsequent effects on water resources planning and development. Data are needed to facilitate preservation of the Nation's important remaining natural areas and historic resources. Adequate information on the extent and integrity of our remaining biotic diversity in the country, including wetland communities, is urgently needed. Research is urgently needed on various topics related to natural area establishment and management so that preservation of genetic diversity within a National system may proceed in a more enlightened way. A resources inventory and plans for management, research, and education are needed for each preserved area.

Analysis of Water Requirements for Public Lands

An important aspect of preserving natural and historic resources and maintaining them for the public benefit is the Nation's public lands. These public lands are largely those managed as Bureau of Land Management (BLM) Lands, National Forests, and National Parks. The operation and management of these lands require minimal water withdrawals which are largely consumptive.

Withdrawals of fresh water for public lands were estimated at 1.238 million gallons per day in 1975, about 0.4 percent of the total for all offstream withdrawals (Table III-70). These withdrawals are expected to increase by 40 percent by 2000, at which time the proportion of National use for these lands will be 0.6 percent.

As expected the largest uses of water on public lands are in the western Regions, the Great Basin, Pacific Northwest, and California; regions which together, withdrew and consumed 71 percent of the total for public lands in 1975. Collectively the regions west of the Mississippi Region withdrew and consumed 98 percent of the total for public lands.

Table III- 70

SUMMARY OF WITHDRAWALS AND CONSUMPTION FOR PUBLIC LANDS BY WATER RESOURCES REGIONS - 1975, 1985, 2000 (MILLION GALLONS PER DAY)

	Withdrawals			Consumption		
Region	1975	1985	2000	1975	1985	2000
New England	1	1	2	1	1	2
Mid -Atlantic	4	4	7	3	3	6
South Atlantic-Gulf	5	6	10	5	6	10
Great Lakes	6	13	17	6	13	17
Ohio	5	8	12	5	8	12
Tennessee	1	2	3	1	2	3
Upper Mississippi	2	3	4	2	3	4
Lower Mississippi	1	3	4	1	3	4
Souris-Red-Rainy	1	2	2	1	2	2
Missouri	159	198	266	159	198	266
Arkansas-White-Red	26	33	39	26	33	39
Texas-Gulf	<1	2	2	<1	2	2
Rio Grande	22	27	28	22	27	28
Upper Colorado	103	120	127	103	120	127
Lower Colorado	20	49	56	19	47	54
Great Basin	319	351	411	319	351	411
Pacific Northwest	190	262	332	190	262	332
California	363	371	394	362	369	391
Alaska	10	10	20	10	10	20
Hawaii	0	0	0	0	0	0
Caribbean	0	0	0	0	0	0
Total, Regions 1-18	1228	1455	1716	1225	1450	1710
Total, Regions 1-21	1238	1465	1736	1235	1460	1730

Nearly 100 percent of public lands withdrawals of freshwater are consumptively used. The public lands will consumptively use about 1.2 bgd in 1975 and 1.7 bgd in 2000. Consumptive uses on public lands were about 1.2 percent of the total national consumption for offstream uses in 1975. Significant savings or improved efficiencies in water use are not contemplated for the Nation's public lands.

These withdrawals of freshwater for public lands substantially understate the real requirements for natural areas and historic resources because of the large holdings in state, local, and private organizations which are not recorded. In addition, the instream flows and stocks needed for natural areas are considered only for fish and wildlife purposes. However, these instream flow approximations required for fish and wildlife should be sufficient for maintaining most natural and historic resources.

Wilderness Areas

The Wilderness Act of September 3, 1964, (79 Stat. 890) established congressional policy "to secure for the American people of present and future generations the benefits of an enduring resource of wilderness." To this end, the Act required the Secretaries of Agriculture and the Interior to review the suitability of their respective primitive and roadless areas for wilderness inclusion.

The 1964 Act declares that areas classified as "wilderness" will be managed in such a manner as to preserve their wilderness character into perpetuity. This should not be construed as a "lock up of resources" but a presentation of those uses which are compatible with wilderness values.

The quality of the surface water is of key importance to the National Wilderness System, not only for its recreational and scenic values, but also because of its importance in maintaining the viability of wilderness areas themselves. Water problems for these areas may in some cases be influenced by conditions and activities upstream. An upstream project may interrupt the normal water flow and alter the wilderness character of an area. Strip-mining upstream, for example, could lower water quality in a downstream wilderness area. Thus, preserving wilderness areas may require that special precautions be taken for certain activities in adjacent areas.

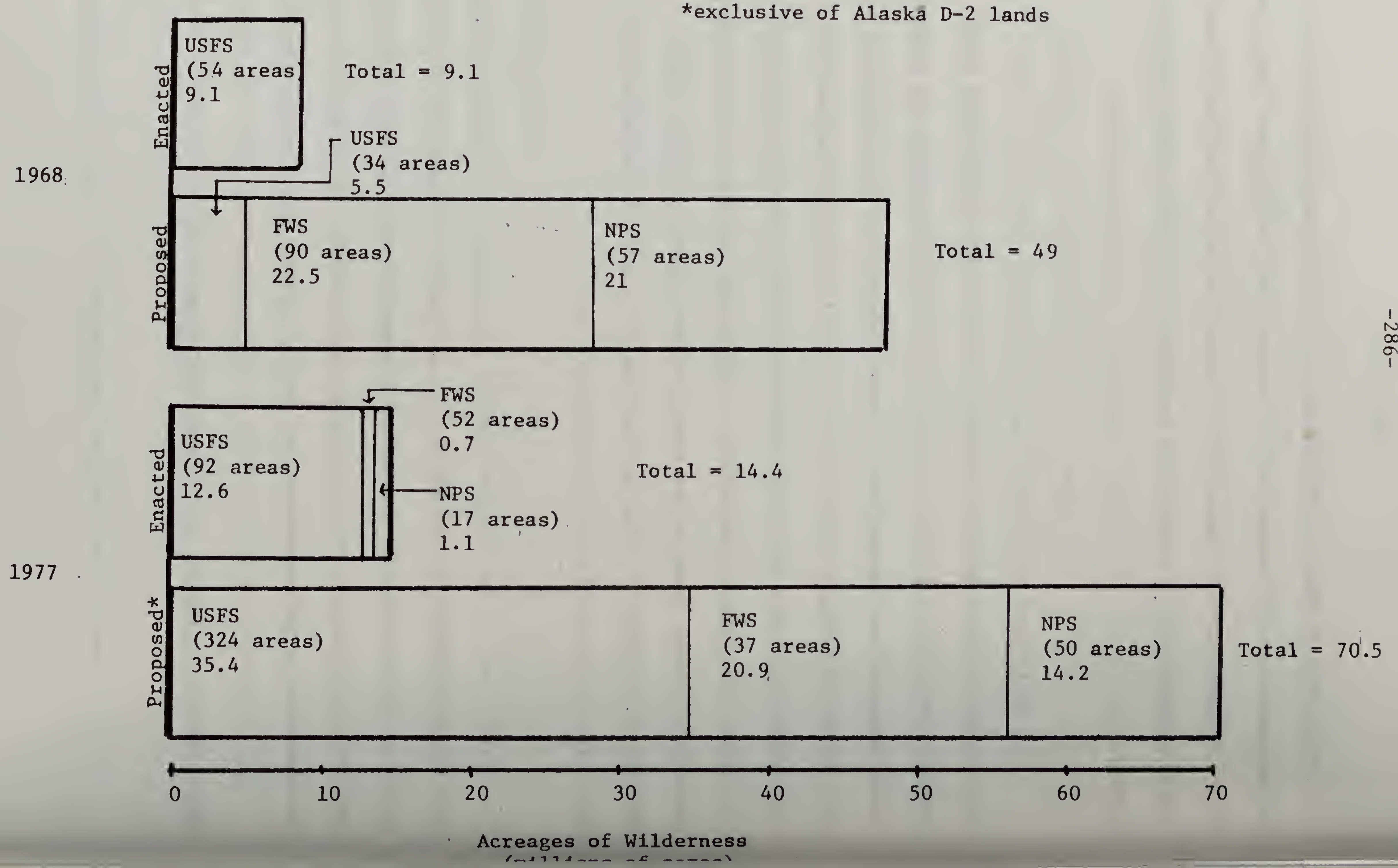
Fifty four of the highest quality areas within the Nation's forests were blanketed into the wilderness system in 1964 (Figure III-31). The number of acres currently listed as wilderness areas is about only one-half of one percent of the total contiguous United States land base, and is about one-third the size of the land area devoted to urban uses.

Opportunities to Expand the Wilderness System

(1) National Forest Roadless and Undeveloped Areas - Anticipating

FIGURE III-31

INCREASE IN EXISTING AND PROPOSED WILDERNESS AREAS FROM THE FIRST TO THE SECOND NATIONAL WATER ASSESSMENT



*exclusive of Alaska D-2 lands

the requirement for completion of Primitive Area Studies that are specified in the Wilderness Act, the Forest Service issued a 1967 directive to the Regional Foresters* to identify all areas which seem to satisfy the criteria meriting recommendation for inclusion in the National Wilderness Preservation System. Subsequent Congressional action has also directed the identification of other eligible lands.

The National Forests contain many areas of significant size that are roadless and undeveloped and are not specifically mentioned in the 1964 Wilderness Act. These lands represent potential high quality additions to the National Wilderness Preservation System. It is proper and essential that they be given special consideration in planning because the irreversible nature of some actions could damage their wilderness character. It is generally accepted that the wilderness characteristics and values that now exist in some roadless areas may be reduced if certain kinds of development are allowed to occur. Areas on which roads are constructed, timber is harvested, land is cultivated, or permanent structures are constructed are essentially precluded from wilderness consideration. With this in mind, the roadless area review was designed to select the remaining areas having highest quality for additional study and to continue to protect their wilderness characteristics until a final determination could be made.

A second roadless area review evaluation (RARE II) was initiated during the final days of this Assessment. It is possible that additional potential wilderness may be identified.

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*Forest Service Manual 2321.31b, Revised 1969. Appendix 11.

(2) The National Park Service and Fish and Wildlife Service have examined the lands under their jurisdication (National Parks and Monuments, and National Wildlife Refuges) to determine those tracts which may meet the wilderness criteria. These areas were then studied and recommendations sent forward for most of those areas (see Wilderness Appendix).

(3) Public domain lands administered by the Bureau of Land Management are not specifically mentioned for study by the Wilderness Act. However, passage of the Federal Land Policy and Management Act of 1976 (P.L. 94-579) extends the provisions of the Wilderness Act to public domain lands. The Bureau administers about 450 million acres of Federal land, including 279 million acres in Alaska. About 322 million of the 450 million acres are roadless and undeveloped. The Bureau of Land Management has designated 11 Primitive Areas (234,013 acres). In addition 27 other areas (1,486,000 acres) have been identified as being primitive in character as of April 1974. There are also 43 natural areas. Such roadless and undeveloped areas are a potential source of classified wilderness. All of these are subject to a current inventory and should be considered in determining the need for areas to be left in an undeveloped state.

(4) The Alaska Native Claims Settlement Act of 1971 (P.L. 92-203) provided for withdrawal of 80 million acreas for study for possible

inclusion in the National Parks, Wildlife Refuge, Forest, and Wild and Scenic Rivers Systems (often termed D-2 lands). The Act sets a deadline of December 1978. In 1973 the Secretary of Interior recommended that 83 million acres be added to these systems and that a three year study of these areas for suitability as designated wilderness be undertaken. Congress is currently working on H.R. 39 which calls for instant wilderness designation for some areas. In September 1977 the Secretary of the Interior presented to Congress the Administration recommendations on H.R. 39 which called for both instant wilderness and wilderness study areas.

Information on these proposed D-2 lands was not included in the wilderness appendix. But they are included in a map, available as a separate product of this Assessment, which illustrates the spatial relationship between the enacted, proposed, and potential wilderness for the four Federal agencies. It is obvious that the wilderness preservation program cannot attain equal distribution by states or drainage basins. Wilderness areas are a national resource whose preservation must be pursued where opportunities exist.

PART III

CHAPTER 12

FLOOD DAMAGE MANAGEMENT AND RELATED RESOURCE CONSIDERATIONS

Floods occur whenever the waters in a stream, lake, or bay exceed the natural or artificial banks. Excessive runoff from snowmelt, rainfall, or a combination of these on frozen ground is responsible for most of the spring flood losses in the northern United States. Thunderstorms, usually in summer, pose the greatest threat to small watersheds throughout the country. Intensive, localized rainfall of short duration from these storms covers cause heavy flash flood damages. Hurricanes and accompanying tidal flooding periodically endanger Gulf and Atlantic coastal areas. The melting of glaciers and breaking of ice-jams produce flooding, particularly along Alaska's arterial rivers.

Direct potential losses of property in the flood plain were projected to be $3.4 billion nationally for 1975. Other, less measurable losses, include funds spent for relief and reconstruction in the area, lost productivity and the general disruption of the economy during and after the flood. Loss of human life and health from floods are tragic especially with the modern communication and weather services available. However, the enormous destructive force of floodwaters, whether coming from a rampaging river or a great wall of tide, is rapidly suppressed in memory or ignored as happening only to someone else, and the occupancy of flood plains continues to grow.

The Nature of Floods

The size of a flood is measured by its area, depth, and duration. A river leaving its banks in a relatively flat area can spread over many miles, resulting in light damage to many properties within the area as well as disruption of commerce and transportation beyond the flooded area. A river with the same volume leaving its banks in a steep valley could flood property to a greater depth and would have a more destructive force. The physical characteristics of the land help determine the flood plain limits for a flood of a given volume.

Water moving in currents and waves produces a tremendous force that dislodges and disrupts and then uses the debris to repeat the process. The water becomes contaminated by oil, chemicals, sewage, or other pollutants picked up by the flood and left behind when velocities abate. Velocity, a major damage factor, is a function of water volume (depth), channel restriction, and gradient all of which can be modified by man.

The timing and duration of a flood can be measured in many ways, most of which describe the extent of loss of life and property. Flash floods, such as the Rapid City flood of 1972, provide almost no time for preparation. The water rises rapidly and the flood is of relatively short duration. Slow rising floods, such as the lower Mississippi flood of 1975, may provide adequate time for warnings but may cause other problems if the river remains in flood for weeks at a time. Reaction

Procedures differ with time of day--light or dark--and depend on whether people are at work, at home, or asleep.

Seasonal flooding may produce a pattern that will permit adequate preparation. Past records are invaluable in making these determinations. A spring flood may come on a more predictable schedule than a thunderstorm.

The Consequences of Floods

The use of flood plains produces both negative and positive results. The negative results include losses of property and life. Flood damages averaged $104 million in the 15 years 1926-1940 but varied from $2.8 million in 1931 to $440 million in 1937 with damages exceeding $50 million about one year of every two. Since 1941 the damages have never been less than $50 million in one year. The most frequent yearly damages lie in the range of $100 million to $400 million although damages of about $1 billion have occurred several times since 1951, the first year damages exceeded $1 billion. Flood damages reached nearly $4.5 billion in 1972, the highest ever (Table III-71). The 1972 flood damage experience was unusually high over a wide area not normally damaged from hurricanes and storms deriving from them. However, there is no evidence that physical floods are increasing in magnitude or frequency. Increases in property damage result from inflation and, more importantly, from new development in flood prone or flood susceptible areas.

Table III-71

ANNUAL LOSSES OF LIFE AND PROPERTY IN THE UNITED STATES FROM FLOODS, 1926-1976

Year	Annual Loss of Property ($1,000)	Annual Loss of Life	Average Loss of Property ($1,000)	Average Loss of Life	Year	Annual Loss of Property ($1,000)	Annual Loss of Life	Average Loss of Property ($1,000)	Average Loss of Life
1926	23,468	16			1951	1,028,741	51		
1927	347,656	423			1952	254,064	54		
1928	44,611	15	99,937	112	1953	122,204	40	501,468	100
1929	68,098	89			1954	106,842	55		
1930	15,850	14			1955	995,491	302		
1931	2,808	0			1956	64,688	42		
1932	10,295	11			1957	360,303	82		
1933	36,679	33	37,454	74	1958	218,255	47	175,495	56
1934	10,362	88			1959	141,255	25		
1935	127,127	236			1960	92,976	32		
1936	282,549	142			1961	154,033	52		
1937	440,738	142			1962	75,237	19		
1938	101,098	180	175,737	121	1963	177,946	39	369,381	66
1939	13,834	83			1964	651,642	100		
1940	40,467	60			1965	788,046	119		
1941	39,524	47			1966	117,004	31		
1942	98,507	68			1967	375,218	34		
1943	199,732	107	120,928	69	1968	339,399	31	391,946	105
1944	101,079	33			1969	902,654	297		
1945	165,798	91			1970	225,453	135		
1946	70,813	28			1971	287,525	74		
1947	272,328	55			1972	4,465,135	554		
1948	229,959	82	168,616	61	1973	1,894,493	148	1,629,431	259
1949	93,931	48			1974*	500,000	89		
1950	176,050	93			1975*	1,000,000	113		

*Preliminary Minimum Estimate

The projection of flood damage losses in 1975, based on loss probabilities, provides another dimension to the problem. It is based on the current level of development and on the extent of flood plain management in effect (Figure III-32). The projected property damage for 1975 (in 1975 dollars) was $3.4 billion. It is this probability loss that is used to project for probable future conditions. Under various assumptions about levels of flood plain regulations that might develop (Figure III-33).

Floods also produce serious health problems; injuries, exposure, stress and strain, and water contamination. These problems continue to exist for some time after the flood has subsided. Massive and expensive relief programs by various levels of government, volunteer help, and charitable organizations are necessary to reduce or prevent health problems such as epidemics. The yearly loss of life from floods has usually been less than 100, but as recently as 1972 the loss exceeded 500 people. These losses of life in time of flood result from many conditions--ignorance, indifference, human failures in operating warning systems, curiousity, samaritan instinct and motivations or circumstances to be in a flooding situation. Flood plain management efforts consider these human factors in planning to keep the losses of property and lives to acceptable or minimum levels.

Floods can be devastating or beneficial to agricultural land. Floods can wipe out crops and dump tons of sand, gravel, clay and other debris on the land. Slow moving floods can bring in fertile, highly

Figure III-32

TOTAL FLOOD DAMAGES BY WATER RESOURCES REGIONS , 1975
(THOUSANDS 1975$)

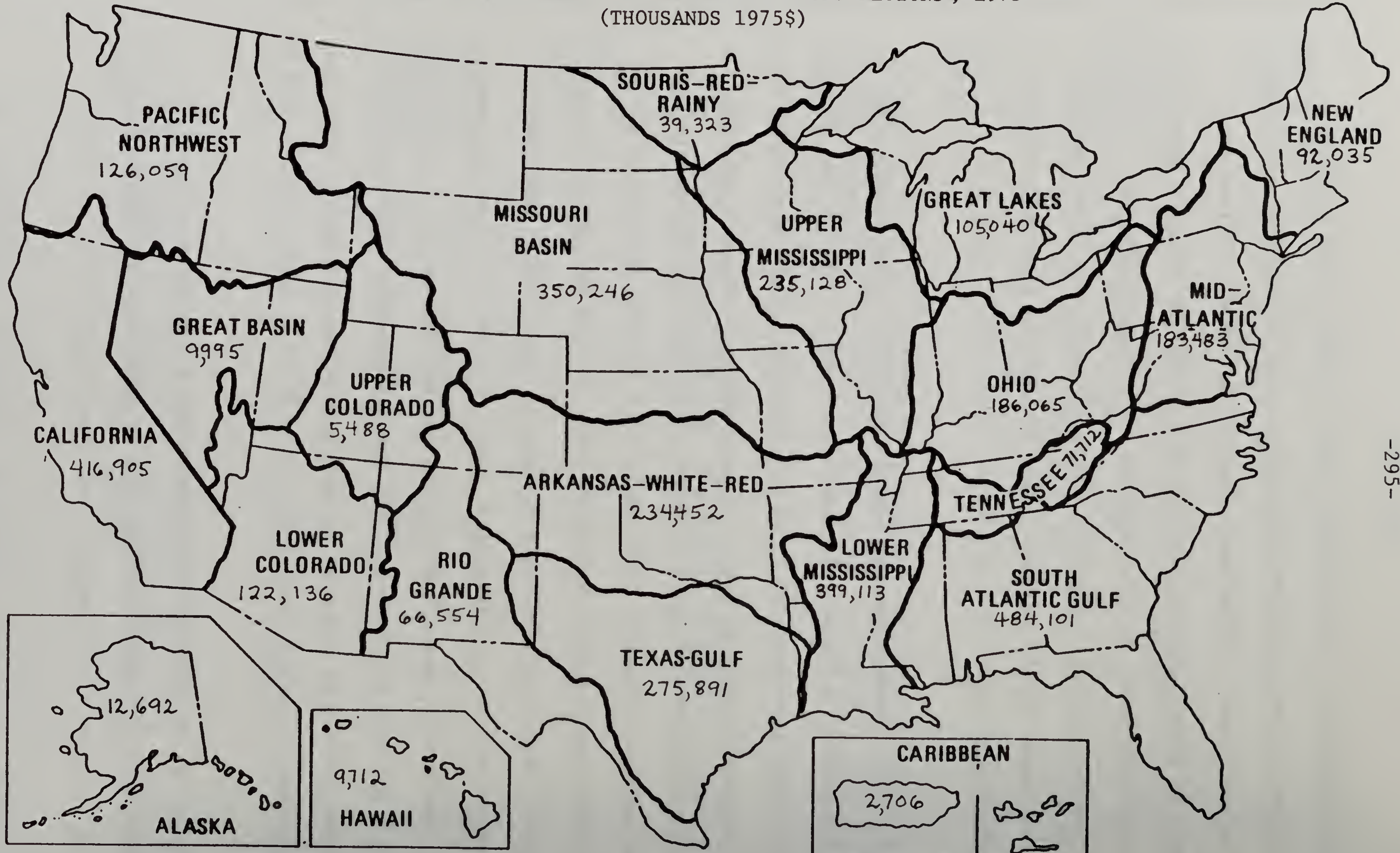
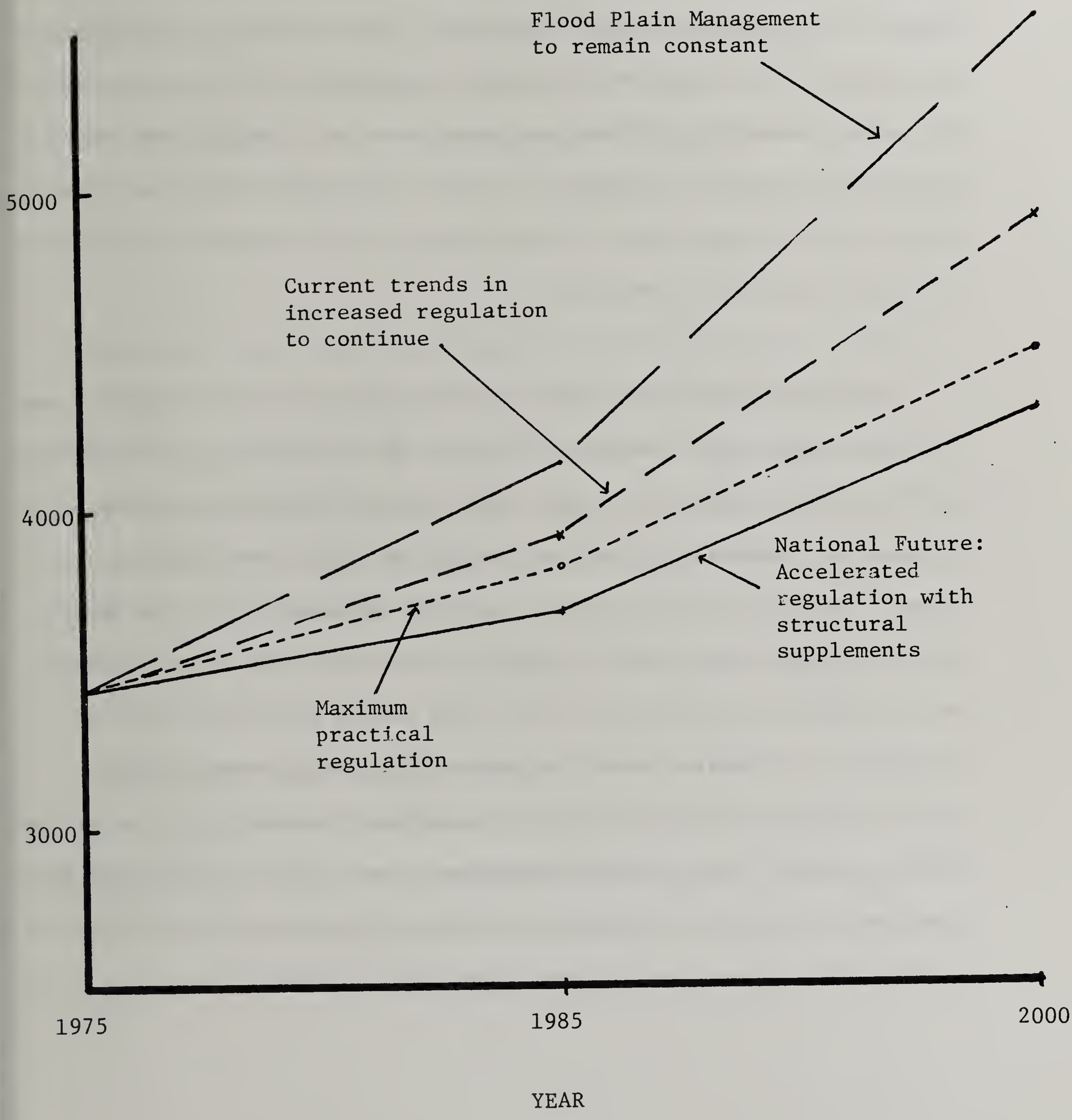

PACIFIC NORTHWEST
126,059
SOURIS–RED–RAINY
39,323
NEW ENGLAND
92,035
GREAT LAKES
105,040
MISSOURI BASIN
350,246
UPPER MISSISSIPPI
235,128
MID–ATLANTIC
183,483
GREAT BASIN
9,995
UPPER COLORADO
5,488
OHIO
186,065
CALIFORNIA
416,905
ARKANSAS–WHITE–RED
234,452
TENNESSEE 71,712
LOWER COLORADO
122,136
RIO GRANDE
66,554
LOWER MISSISSIPPI
399,113
SOUTH ATLANTIC GULF
484,101
TEXAS-GULF
275,891
12,692
ALASKA
9,712
HAWAII
CARIBBEAN
2,706

Figure III-33
PROJECTED AVERAGE ANNUAL FLOOD DAMAGES
FOR SELECTED ALTERNATIVE MANAGEMENT SCENARIOS



productive soil. As the floodwaters recede planting or replanting may take place, and, in some cases, better crops result. Obviously the type of erosion and sediment and the timing and duration of flooding determines whether soil enrichment takes place.

Other types of enrichment can be found in wetlands and other natural areas where periodic rejuvenation keeps feeding and breeding areas alive. Such areas are dependent on periodic flooding or at least high water tables in marshland and swamp areas to stimulate and support resident and transient wildlife. Further, these areas serve as valuable natural flood storage areas of considerable capacity and often provide necessary ground water recharge.

Every big flood brings sympathy and assistance to its victims from both private and public sources--citizens and governments alike respond to the disaster. But then, great pressures are brought to bear on governments, especially state and Federal, to solve the problem. Federal concern for flood control was first advanced in the Sacramento and Mississippi River Basins in 1917. In the mid-1930s severe floods twice struck the northeast section of the United States and the Ohio River Basin. Property damage throughout the country exceeded $100 million dollars four years in a row, an amount exceeded only once in the previous decade. Each year now finds one or more large floods occurring somewhere with the current average projected damages of about $3.4 billion. The damages continue to increase.

Flood damages and the spectre of catastrophe shape so much of the thinking about flood plain and related issues that the true nature of flooding and the basis of the damages is not understood, or more tragically, not dealt with. Floods are probabilities. They are random experiences in the minds of people, but they produce annual, actual losses in lives and dollars. In this analysis experienced or historical losses are the direct primary losses only which are identified by year of occurrence. On the othr hand, the term "average annual" is used to express the probability of loss in a current of future year. There is no check basis for "comparing" historical yearly losses with "probable" average annual losses.

Systematic flood damage estimates for the Nation have not been made. Reported losses are aggregates of best estimaters made by a variety of sources--some trained observers (claims adjustors, damage estimators) and some not trained (news reporters, eyewitnesses, politicians). Disaggregation of national data to regions or aggregation of regional data on flood damages is not well controlled statistically. But the damages do exist and the immediate burdens occur in the flood plains.

Because the flood damage problem is a dual one which exists only when two conditions are met--floods and flood plain occupancy or use--both conditions must be considered in the solution. These conditions are recognized in the emerging flood plain management approach which sets out a reasonable future role for the flood plain, recognizing present and future problems related to utilization and then adjusting flood plain occupancy to the "reasonable" role. Nonstructural flood plain solutions alone will not achieve the objectives of minimizing the combination of losses, both actual and foregone opportunities, from flooding and flood plain occupancy. One must select from a large array of measures such as dams, land treatments, and levees--to modify flood behavior and flood plain regulations, flood proofing, public acquisition, and evacuation to modify occupancy of the flood plains. These tools are selected in the flood plain management program to overcome existing and anticipated problems and also for enhancement and protection of natural resources in flood plains.

A key to flood plain management is the local decision process and local responsibility for flood plain regulation. This chapter traces some of the conditions, concepts, and actions that follow from this sequence of evolution in the recognition of both floods and flood plain occupancy as a dual condition of flooding problems.

Current and Future Probable Flood Damages

Flood damage estimates for the Nation are based on various assumptions about future land use and flood damage management programs. The national estimates are aggregated from regional projections based upon probabilities of recurring damages under several assumptions about flood plain management and regulation relative to flood plain development.

Regional estimates in the Second Assessment have been adusted to recognize that structural measures are likely to be playing a declining role and regulatory measures an increasing role in flood plain management. The Soil Conservation Service and Crops of Engineers developed current estimates of average annual flood damages for each aggregated subregion and projected average annual flood damages to the years 1985 and 2000 for four alternative levels of flood plain management; i.e., (1) current (1975) level of flood plain management to remain constant, (2) continuation of current rate of flood plain regulation, (3) flood plain regulation to the maximum practical extent, and (4) acceleration of current trend in regulatory measures plus installation of structural measures at a slower rate. The fourth alternative is assumed most likely to occur. Accordingly, the latter projects the most probable average annual flood damages for the years 1985 and 2000 (Table III-72). The current estimates were derived from inventories of market value damages and losses by the Soil Conservation Service for drainage areas generally exceeding 400 square miles.

After examining data and investigating likely trends in flood control work, the fourth alternative was developed, which reflects the damage reduction from structures amounting to 0.4 percent per year of projected damages remaining assuming regulation trends continue. The fourth alternative assumes an increasing role for regulatory measures and a declining role for structural measures. Flood plain regulations will be implemented at a rate faster than the current rate but not up to

Table III-72
PROJECTED AVERAGE ANNUAL FLOOD DAMAGES
FOR THE UNITED STATES FOR SELECTED ALTERNATIVE MANAGEMENT SCENARIOS, 1985 and 2000

Future Alternatives (Policy and/or cases)	MILLIONS OF 1975 DOLLARS					
	Urban & Built-up Areas	Agri.	Other	Total	Upstream	Downstream
1985						
1 Flood Plain Management to remain constant	1554	1677	922	4153	1889	2264
2 Current trends in increased regulation to continue	1424	1679	803	3906	1819	2087
3 Maximum practical regulation	1358	1677	799	3834	1775	2059
4 Accelerated regulation with structural supplements	1306	1609	764	3679	1746	2004
2000						
1 Flood Plain Management to remain constant	2240	1942	1378	5560	2646	2914
2 Current trends in increased regulation to continue	1855	1944	1130	4929	2409	2520
3 Maximum practical regulation	1459	1944	1101	4504	2088	2416
4 Accelerated Regulation with Structural supplement	1575	1749	1002	4326	2163	2263

*Denotes the adopted National Future (NF) alternative the maximum practical level. Structural measures will continue to be installed but at a slower rate than in the recent past. This alternative is believed to be the one that society is most apt to choose.

Estimates of probable flood damages for this assessment totaled above \$3.4 billion for 1975 (Table III-73). These probable damages, based on the National Future (Modified Central Case with improvements in flood plain management), are projected to increase by 26 percent from 1975 to 2000 when probable damages would be \$4.3 billion (1975\$). In 1975 these damages were impacted on agriculture most heavily (nearly 48 percent of the total) and secondly on urban areas (one-third of the total). Other flood damages to public lands, mining, public facilities and utilities, rural industries, etc. were estimated at 19 percent of the total.

Agricultural flood damages in 2000 are projected to be over \$1.7 billion, only 40 percent of the total and decline relative to urban and other damages. The increase in agricultural damages is projected at only 7 percent for the 1975-2000 period.

Urban flood damages in 2000 are projected to increase by 37 percent to a total of nearly \$1.6 billion or 36 percent of the total. Other flood damages are projected to increase by 55 percent of a level of \$1 billion or 24 percent of the Nation's probable flood damages for the assumed future conditions in year 2000. These projected damage increases, giving consideration to flood plain management (structural and non-structural measures), are based on assumptions of more intensive use of

Table III-73

SUMMARY OF ANNUAL TOTAL, URBAN, AGRICULTURAL, AND OTHER FLOOD DAMAGES BY WATER RESOURCES REGIONS
(MILLIONS OF 1975 DOLLARS)

Region	Total Flood Damages			Urban Flood Damages			Agricultural Damages			Other Flood Damages		
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000
New England	92	121	153	77	103	128	3	3	3	12	15	23
Mid-Atlantic	183	213	296	130	158	229	28	26	28	25	28	39
South Atlantic Gulf	484	528	658	110	133	177	264	254	281	110	140	199
Great Lakes	105	125	146	79	96	111	20	19	24	6	10	10
Ohio	186	201	232	60	69	82	86	88	94	40	44	56
Tennessee	72	76	93	20	23	29	35	32	34	17	21	29
Upper Mississippi	235	258	302	70	77	86	108	114	131	57	67	86
Lower Mississippi	399	420	469	63	73	88	255	256	273	82	91	108
Souris-Red-Rainy	39	41	47	6	6	7	29	30	32	5	6	8
Missouri	350	358	413	52	59	70	223	214	235	76	85	108
Arkansas-White-Red	234	249	303	39	50	65	146	135	144	50	64	93
Texas-Gulf	276	282	302	50	47	50	176	177	188	50	58	64
Rio Grande	67	67	72	12	13	15	44	42	44	11	11	13
Upper Colorado	5	6	8	1	2	2	3	3	4	1	2	2
Lower Colorado	122	137	158	56	65	79	38	39	38	28	34	41
Great Basin	10	11	14	3	4	5	4	4	4	3	3	4
Pacific Northwest	126	134	158	42	49	61	67	64	71	17	21	26
California	417	433	482	259	269	275	101	102	115	56	62	92
Alaska	13	3	5	13	3	4	1	1	1	1	1	1
Hawaii	10	10	11	5	6	7	4	4	4	1	1	1
Caribbean	3	3	4	1	1	2	1	2	2	1	1	1
Total, Regions 1-18	3404	3663	4306	1129	1296	1562	1629	1603	1743	646	763	1001
Total, Regions 1-21	3429	3679	4326	1147	1306	1575	1635	1609	1749	647	764	1002

flood plains and higher value of properties subject to flood damage. Projected flood damages would be $0.8 billion more if the flood plain management measures assumed in the Second Assessment are not implemented. The total loss of human lives from floods from 1925 to 1970 was 3,738. The number of flood related deaths may vary widely from one year to another, and no estimates were projected for this Assessment.

Generally the regional estimates and projections of flood damages follow the population densities. The highest damages will occur in the South Atlantic-Gulf, California, and Missouri Regions. Agricultural damages are most significant in the South Atlantic-Gulf and Missouri Regions (also including the Upper and Lower Mississippi, Arkansas-White-Red and the Texas-Gulf Regions). While urban damages are and will be more prominent in California (along with the New England, Mid-Atlantic, and Great Lakes Regions).

Flood Damage Management

Whether it is channel straightening and deepening or the holding and timely releasing of impounded water large flood discharges can be accommodated with little damage occurring on the flood plain. During FY 1974 the savings from structural protective measures totaled $6.5 billion, and the cumulative savings over the years has been estimated at $40 billion. But all areas cannot be given this kind of protection, even if warranted, nor are all flood control works certain to prevent catastrophic results. They often give a false sense of security and invite further invasion of the floodplain.

Indiscriminate construction in flood plains without regard to what is built or where and how facilities are built is bringing pressures to deny all development in on flood plain or at least to require a difficult process for obtaining a permit. Whole systems of flood plain regulations--zoning, building codes, and subdivision regulations--are being enacted locally and financial pressures are being applied nationally. (Table III-74). Essential buildings may be flood proofed through closures, seals, and anchors or elevated.

Structural Measures

The Corps of Engineers and Soil Conservation Service have active flood control, flood prevention, and watershed protection programs. Much of their activity has involved structural measures for which expenditures have averaged over $600 million per year for the last 10 years. Although emphasis is being put on nonstructural measures significant expenditures are likely to continue to be made for structural measures such as dams, levees, and channels.

The First Assessment shows that cumulative damages prevented in downstream reaches by structural measures increased from $5.0 billion in 1950 to $14.6 billion current dollars in 1966.

Table III-74
FLOOD PLAIN MANAGEMENT INFORMATION ASSISTANCE ON ADOPTION OF FLOOD PLAIN REGULATIONS

Uses Made of Flood Plain Regulations	Numbers Of Uses Thru FY		
	1974	1975	1976
Adoption or strengthening	1003	1289	1590
Process of adoption	273	285	300
Planning studies underway	838	923	1096
Interim flood control	1522	1978	2448
Non-Federal flood control work	110	118	138
Non-Federal control studies	362	391	420
Acquisition of flood plains	543	656	734
Comprehensive land use planning	1746	2023	2315

Note: These actions have in many cases been prompted by interaction of local interests and Corps of Engineers Flood Plain Management Services. Total responses to requests for flood hazard information and assistance numbered 19,000 in FY 1976.

Source: Corps of Engineers, Flood Plain Information Report (FPIR)

The 1975 $3.4 billion annual damages would have been 40 percent larger if structural projects had not been installed. If the current trend continues structural measures alone would reduce projected damages by another 10 percent by the year 2000. Use of structural measures for flood control and protection has been considerably less than the maximum practical. White and Hass* contend that, "It should be possible to reduce annual losses by at least 20 percent if the economically feasible works could be built rapidly and cheaply enough."

Flood Plain Regulation

Flood plain regulation is the adoption and use of legal tools to control flood plain uses. For this report regulation includes zoning, some construction requirements and, to a limited extent, land acquisition or some other equitable arrangement (such as subsidies or tax incentives) to implement the regulation. Enforcement and compliance with regulations are assumed in the projections. Warning and evacuation procedures, floodproofing of most properties, and aggressive flood plain acquisition programs are not included. Perhaps two-thirds of the potential flood damage reduction from nonstructural measures could be realized from regulation.

Recently emphasis has been placed on the use of nonstructural measures to reduce flood damages. Federal flood insurance became an operating reality through the Flood Insurance Act of 1968 (P.L. 90-448) and reinforced by the Flood Disaster Protection Act of 1973 (P.L. 93-234). Within the past seven years over 12,000 communities have participated in the Federal flood insurance program. Land use management policies suggested by a National task force in 1966 are beginning to operate at the working level as the result of Federal Executive Order 11296 and new administrative procedures. The National Disaster Relief Act of 1974 (P.L. 93-288) has provided new Federal assistance and disaster mitigation policies. The Flood Insurance Act of 1968 provided Federal incentives that have resulted in increasing land use regulation by local agencies. State agencies have been given additional authority to deal with flood problems. Reports on flood hazard insurance, protection, and prevention, and flood plain information have been prepared for over 5,800 communities. Indications are that Insurance, floodproofing, and land use management are taking an increasing share of the mix of adjustments to flood hazards.

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*Gilbert F. White and J. Eugene Hass, Assessment of Research on Natural Hazards. The MIT Press, Cambridge, Massachusetts, 1977.

Legislative opinion seems favorably disposed toward increasing use of nonstructural measures as apparent in Section 73(a) of the Water Resources Development Act of 1974 (P.L. 93-251). Section 73(a) reads: "In the survey, planning, or design by a Federal agency of any project involving flood protection, consideration shall be given to nonstructural alternatives to prevent or reduce flood damages including, but not limited to, floodproofing of structures; flood plain regulation; acquisitionon of flood plain lands for recreational, fish and wildlife, and other public purposes; and relocation with a view toward formulating the most economically, socially, and environmetally acceptable means of reducing or preventing flood damages."

If current regulation trends continue, damages would be reduced 14 percent by 2000. The reduction of urban damages would be 23 percent of which the reduction of agricultural damages would be negligible. A review of available data indicates maximum practical regulation could reduce damages 21 percent. The estimate approaches the maximum 25 to 35 percent reduction suggested by White and Haas. Their conclusion was that it seems possible that as much as 25 to 35 percent of mean annual losses could be reduced over a period of 20 years by a combination of measures other than construction of protection works.

Flood Damage Assistance and Flood Plain Management

In urban areas land use and construction controls will be more effective than elsewhere in slowing down the rate of increase of flood damages. States, counties, and cities, however, will have to take their obligations seriously to enforce regulations and ordinances if flood losses are to be kept down. Equitable arrangements need to be insituted for social acceptance. Agricultural damages are not expected to be substantially reduced by flood plain regulation; in fact, they may be increased in some instances where regulations may cause intensification of agriculture. A lag exists from the time when regulations are adopted until they can be fully implemented and the ensuing benefits realized. The beneficial effects of regulation will become more apparent as time progresses.

Flood hazard problems may be alleviated by modifying the susceptibility of people and their property to flood damage, to the characteristics of flooding, and to the consequences of flooding. These approaches can be achieved by applications of the following measures: (1) modifying susceptibility to flood damage and disruption with flood plain regulation, development and redevelopment policies, disaster preparedness and response planning, flooding proofing, and flood forecasting and warning systems and emergency plans; (2) modifying floods (structural measures) with dams and reservoirs, dikes, levees, and floodwalls, channel alterations, high flow diversions, and spillways, land treatment measures, and on-site detention measures; and (3) modifying the impact with information and education, flooding insurance, tax adjustments, flood emergency measures, and/or post flood recovery.

Since 1936 the Federal Government has spent more than $13 billion for dams and other structures such as levees, floodwalls, and channel work. There has also been a substantial non-Federal costs for flood control measures. These non-Federal expenditures are considerablely below the maximum amount which could be economically justified and which could conceivably be in the vicinity of $1 billion per year for the next quarter century.

Federal disaster assistance alone, exclusive of the programs of the Small Business Administration and Farmers Home Administration, obligated $1.3 billion for 210 major disasters during the years between 1970 and 1975. Nearly 21,000 communities have been identified as having flood problems and 30 percent of these communities have populations over 2,500. Reports to assist local planners on flood plain management have been prepared for over 5,800 communities. The Federal flood insurance program makes available Federally subsidized flood insurance to alleviate some of the financial losses. The insurance program requires from covered communities a commitment to regulate flood plain land use. Communities need to adhere to their commitments. Of the 13,000 participating communities over 12,000 need mapping and reports to convert from the emergency to the regular program. Mapping activity needs to be accelerated.

Public perception of flood hazard and appreciation of hazard reduction efforts need to be more sharply focused. Forecate and warning systems need to be improved. The environmental impact of flood control measures has to be assessed on a project-by-project basis. General statements, however, can provide some insight into the relative environmental impact of flood plain management measures. Usually, the adverse environmental impact of nonstructural measures will be minimal compared to structural solutions. Nevertheless, the potential for both positive and negative impacts, whether structural or nonstructural measures are employed in flood plain management, indicates that no predetermined choice should be made. Programs should be developed that give full consideration to the specific situation being faced, and the attendant decisions should be focused on providing the greatest social well-being at the lowest possible cost with the least adverse affect.

PART III

CHAPTER 13

EROSION AND SEDIMENTATION MANAGEMENT

Land Resource Base

Much of the high standard of living in the United States can be attributed to a rich land-resource base. The land productivity has provided ample agricultural products for population with an exportable surplus of agricultural products and an exportable surplus.

While the characteristic high level productivity has been taken largely for granted, the fertile top soil is being lost through erosion and resulting sedimentation is generally causing other problems of pollution and undesirable deposition.

This part addresses these problems. Table III-75 presents the uses of the land in the United States and Figure III-34 shows the percentages distributions of land use in the United States.

Erosion and Sedimentation Problem Summary

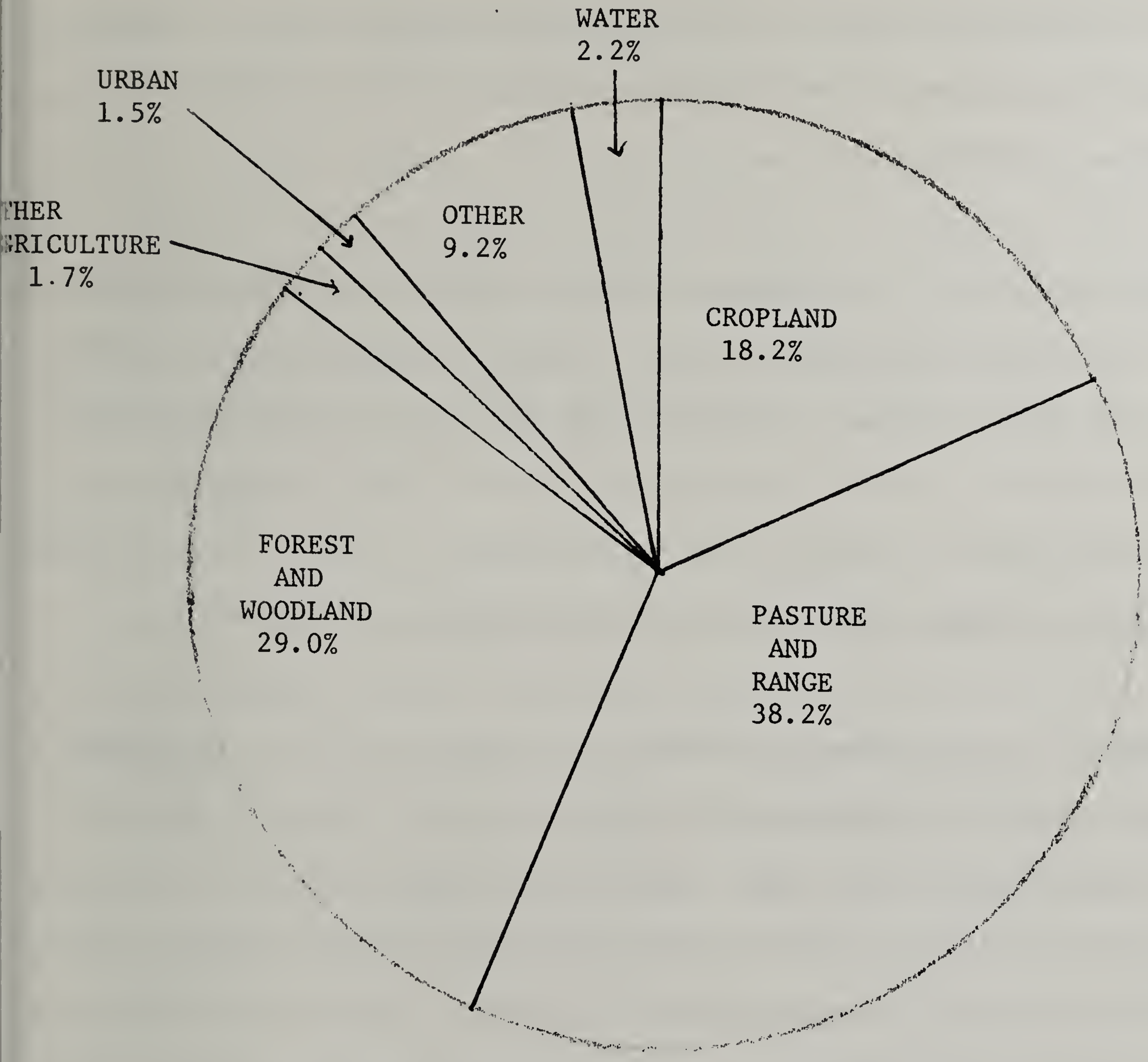
Erosion and sedimentation are a dual phenomena of detaching and moving soil from one place to be deposited in another by the natural forces of water, wind, and gravity. The rates of depletion and accretion vary naturally with the variations in the forces of the agents, and both may be accelerated or decelerated, sometimes even managed, by the activities

Table III-75

SURFACE AREA AND LAND USE, 1975

	Surface Area			Land Use					
Regions 1-21	Total	Water	Land	Cropland	Pasture & Range	Forest & Woodland	Other Agri.	Urban	Other
1,000 Acres	2,316,966	50,114	2,266,852	422,182	884,932	673,313	38,905	34,896	212,624
Percentage	100.0	2.2	97.8	18.2	38.2	29.0	1.7	1.5	9.2

Figure III-34
PERCENT DISTRIBUTION OF LAND USES IN THE UNITED STATES, 1975



Note: Percentages are of total area, including water surface

Other: Includes small water areas

Water: Large inland water areas

Regions 1-21 Large inland water areas

of man which affect either the soil and associated products or the agents and associated forces. Both erosion and sedimentation are usually damaging to resources and economies but on occasions may enhance man's natural and economic world.

Geologic erosion is an historic process that helped form the mountains, plains, and hills on the earth's crust. Dramatic examples are the Grand Canyon and Dakota Badlands. Sediment from this erosion contains millions of dollars worth of nature's nutrients so vital to food production and to the maintenance of natural areas and ecosystems. Productive agricultural floodplains, deltas, and swamps can be maintained by sedimentation.

Sediment is the largest pollutant, by volume and weight, of waters. Sediment, transported and deposited by water, causes damage to cropland, pasture land, forest land, urban areas, rivers, lakes, and bays. It can reduce the capacity of stream channels and cause overwash, swamping, and increased flooding. It accumulates in reservoirs, reduces the efficiency of hydroelectric power facilities, increases treatment costs of municipal and industrial water supplies, impairs navigation, clogs irrigation systems and drainage ditches, destroys harvestable crops, increases maintenance costs of utility and transportation facilities, decreases the recreational value of some waters, and adversely affects the fishery resource.

Sediment can also be beneficial. Added to the flood plain, it may provide more land for growing crops and even improve the quality of some croplands. Without sediment transported to the coastal areas our recreation beaches would never be replenished from the eroding effect of waves and littoral currents. Streams deprived of sediment from nearby lands will, because of their natural energy available for transport, pick up more particles from their banks and beds to compensate for reduced amounts of soil delivered by rainfall runnoff. The same pheonmenon occurs in rivers when the construction of dams and reservoirs upstream cuts off sediment supply.

Such are the contrasting effects of the largely unseen process of erosion and sedimentation. Geological erosion, over which man has little control, continues to occur, most visibly in the arid, western portion of the Nation. However, most of the Nation's erosion and sedimentation problems are caused by man's activities. Erosion and sedimentation throughout the Nation are in large part caused by improper land management practices on areas such as cropland, pasture, rangeland, forest land, strip mining land, construction sites, streambanks and shorelines.

Against the background of geological erosion man accelerates the process by changing cover and altering the hydraulic system through which the water and sediment are transported. These alterations occur principally in cropping, irrigation, livestock production, logging, mining, recreation, and construction. Under some circumstances it is not uncommon for man's activities to increase erosion rates by more than 100 fold over the normal or geological rate (Table III-76). Generally erosion depletes the productive value of land.

In addition, man may be able to change runoff conditions by cloud seeding or by irrigation. Runoff conditions from land surfaces can be changed by conservation practices, and hydraulic characteristics of flow in channels can be changed by structural works or by altering the natural characteristics of stream channels. All have a profound influence on erosion and sedimentation.

Erosive Agents

The principal agents of erosion are water, wind, and gravity, but water is the major factor. Even when wind or gravity is the moving force, water affects the process. Dry, pulverized soil is highly vulnerable to wind erosion and steep, wet soils are more susceptible to gravity erosion-mudslides and landslides.

Water is the chief agent of erosion. It interacts with soil in complex ways to produce various types of erosion such as, sheet, rill, gully, channel, streambank, and shore erosion. An estimated 3 billion tons of soil is lost annually from cropland alone, from the effects of water erosion. Without existing conservation practices, cropland soil

Table III-76
SELECTED QUANTITATIVE EFFECTS OF MAN'S ACTIVITIES ON SURFACE EROSION

Initial Status of Land Use	Type of Disturbance	Magnitude of Impacts by the Specific Disturbance 1/	
Forestland	Planting Row Crops	100 to 1,000	Times
Grassland	Planting Row Crops	20 to 100	Times
Forestland	Building logging Roads	220	Times
Forestland	Woodcutting and Skidding	1.6	Times
Forestland	Fire	7 to 1,500	Times
Forestland	Mining	1,000	Times
Row Crop	Construction	10	Times
Pastureland	Construction	200	Times
Forestland	Construction	2,000	Times

1/ Relative magnitude of surface erosion from disturbed surface, assuming "1" for the initial status. The first row of the table, for example, indicates that transforming a forestland into row crops may increase surface erosion 100 to 1,000 times.

Source: Loading Functions for Assessments of Water Pollution from Non-Point Sources, Environmental Protection Technology Series, U.S. Environmental Protection Agency, Washington, D.C., May 1976.

losses would be another one billion tons annually. Estimates are that the productivity of the soil resource base cannot be maintained at soil loss rates in excess of 1.5 billion tons a year from water erosion. Therefore, much of our cropland is loosing topsoil at rates over twice the level at which existing levels of soil productivity can be sustained on a permanent basis. The amount of sediment being produced from erosion of urban areas, roadsides, strip mines, and from channel banks and bottom has not been estimated on a national basis.

Wind erosion may occur wherever a loose, dry pulverized and unprotected soil is subject to high winds. Generally, it is most serious where precipitation is low and variable, drought is frequent, and temperatures are high. The upper reaches of the Missouri, Arkansas-White-Red, Texas-Gulf, Rio Grande; the Upper and Lower Colorado, the Great Basin, and part of the Great Lakes Region are all areas of high wind erosion hazard, but these losses are not well documented.

Gravitational forces generally cause slow movements of soil, but occasionally the movement is sudden in the form of mudflows and landslides. Mass soil movement may constitute the dominant process of erosion in areas with exceptionally steep slopes, high rainfall, or low-strength soil, such as the mountainous areas of Southern California. Because such movement is only locally important it is not considered further in this Assessment.

Water Induced Erosion and Sediment

The locations of erosion and sources of sediment include: cropland, pasture, range and forestlands, urban and highway construction areas, surface mines, channels (streams and rivers), and coastal areas (ocean and lake shores). Most of the soil eroded from these lands is deposited close to the site of erosion in land depressions, on channel bottoms or floodplains and in lakes and reservoirs. Only about one quarter is carried out to the sea. Procedures have been developed that are useful in estimating soil losses and devising erosion control measures for these areas and conditions.

The most frequently used measure of sheet and rill soil losses from water erosion is the "Universal Soil Loss Equation", a predictive model based on such factors as rainfall, soil types, slopes, management, and control practices (See Erosion and Sedimentation Appendix, this Assessment, or Agriculture Handbook No. 282 for Details). Mathematical models exist for predicting the sediment yield from small acreages and for river basins. It is important to verify these models from known or measured inputs and outputs for each local application.

The percentage of sediment delivered from the erosion source to any specified downslope location is affected by such factors as size and texture of erodible material, climate, land use, local environment, and general physiographic position. In some cases the collecting waterways immediately adjacent to the sediment source can retain 75 percent or more of the eroded soil. The rate at which sediment is discharged to the oceans is usually less, and often much less, than one-fourth of the rate at which it is eroded from the land surface. Several measures ar commonly used to estimate sedimentation:

- Sediment yield or the total sediment outflow from a watershed or drainage basin measured at a specific point and within a specified time period;

- Sediment delivery ratio or the percent of onsite eroded material that reaches a given measuring point; or

- Total sediment load or the combined bed load (the coarser material traveling on or just above the stream bottom) and suspended load (sediment distributed from the water surface to the bed load) in a stream.

While it is difficult to trace the course and speed of sediment movement from a specific type of source such as sheet erosion on cropland, gully erosion, or streambank erosion, existing measurements "... have provided the basis for predicting differences in expected sediment production from various sources" and there are "first approximation of expected effects of land-use developments on future sediment discharge from watersheds."*

Water Induced Erosion and Sediment Sources

Until recently erosion and sedimentation attentions were on cropland where the economic impacts of erosion have been more apparent. However, other settings for erosion are now being studied more urgently as the pressures of man's activites and expanding population are felt in previously undisturbed areas. The Nation's demand for more energy, for instance, has increased strip mining in vast areas of the West and parts of the interior and the East. And, as more people have settled in coastal and urban areas and working hours have been reduced, pressures on woodlands and beaches have intensified.

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* Anderson, Henry W., "Relative Contributions of Sediment from Source Areas and Transport Processes," paper presented at the Symposium on Forest Land Uses and Stream Environment, Oregon State University, 1970.

The areas of concern to the soil and water resource managers now include: Cropland; Pasture, Range and Forest land; Urban Areas; Surface Mines; Channels (streambanks and waterways) and Shoreline (coastal areas, beaches, and marshes).

Cropland

In 1975 just over 50 percent of the 335* million acres of harvested cropland was subject to moderate, severe or very severe erosion (Table III-77). The ten regions with high percentages of moderate to very severe erosion hazard are: New England (55.6), Mid-Atlantic (66.1), South Atlantic-Gulf (52.9), Tennessee (71.6), Souris-Red-Rainy (56.1), Arkansas-White-Red (51.9), Texas-Gulf (54.1), Missouri (61.3), Upper Colorado (81.9), and Pacific Northwest (63.1).

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* Estimated acres harvested in actual year 1975.

Table III-77
SUSCEPTIBILITY OF HARVESTED CROPLAND TO EROSION BY WATER RESOURCES REGIONS, 1975
(1,000 ACRES)

Region	Susceptibility to Erosion				Total Cropland Harvested *
	Slight	Moderate	Severe	Very Severe	
New England	461	529	44	4	1,038
Mid-Atlantic	2,893	4,759	668	226	8,546
South Atlantic-Gulf	9,134	9,402	635	235	19,406
Great Lakes	13,378	7,469	405	125	21,377
Ohio	15,115	9,225	1,202	367	25,909
Tennessee	795	1,628	254	127	2,804
Upper Mississippi	27,108	24,250	1,903	618	53,879
Lower Mississippi	14,016	2,843	219	101	17,179
Souris-Red Rainy	7,600	9,518	237	84	17,439
Missouri	31,118	41,399	6,322	1,528	80,367
Arkansas-White-Red	16,902	14,733	3,059	456	35,150
Texas-Gulf	9,958	10,302	1,208	232	21,700
Rio Grande	1,776	368	38	6	2,188
Upper Colorado	155	464	205	30	854
Lower Colorado	1,197	56	3	4	1,260
Great Basin	924	630	102	9	1,665
Pacific Northwest	5,555	7,778	1,484	230	15,047
California	6,936	1,840	463	109	9,348
Total, Regions 1-18	165,021	147,193	18,451	4,491	335,156

Source: USDA, "Cropland Erosion by Water"

*1975 Cropland is estimated acres havested in the actual year 1975. It is distributed to regions on the basis of the 1967 Conservation Needs Inventory.

The average soil loss rate for most soils should not exceed five tons per acre annually for sustained crop production. But in 1975 the average rate was nearly double this amount nationwide at 9 tons per acre with some subareas exceeding 25 tons per acre (Figure III-35 and Table III-78). Overall erosion dislocated 3 billion tons of soil on harvested cropland in 1975. Without existing conservation measures, the loss would have been 4 billion tons. Estimates of cost burdens for erosion vary widely. One study places the value of soil nutrient losses at $1.2 billion annually.* To date public expenditures for erosion control approximate $15 billion for the last 40 years. The Assessment's national future shows reducing cropland erosion from 9 tons per acre annually to only 4 tons per acre; expenditures of about $35 billion would be required.

The conflicts between increased food production and water quality are covered more fully elsewhere in this report. But it is important to note that certain trends in land use and agricultural practices have hastened erosion. The use of machinery that compacts soil and increases runoff, monoculture, use of marginal lands, and irrigation are prevailing cropping practices which increase soil erosion and sedimentation.

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* U.S. Senate, "Conservation of the Land and the Use of Waste Materials for Man's Benefits," prepared for the Committee on Agriculture and Forestry by the Council for Agricultural Science and Technology, GPO, 1975.

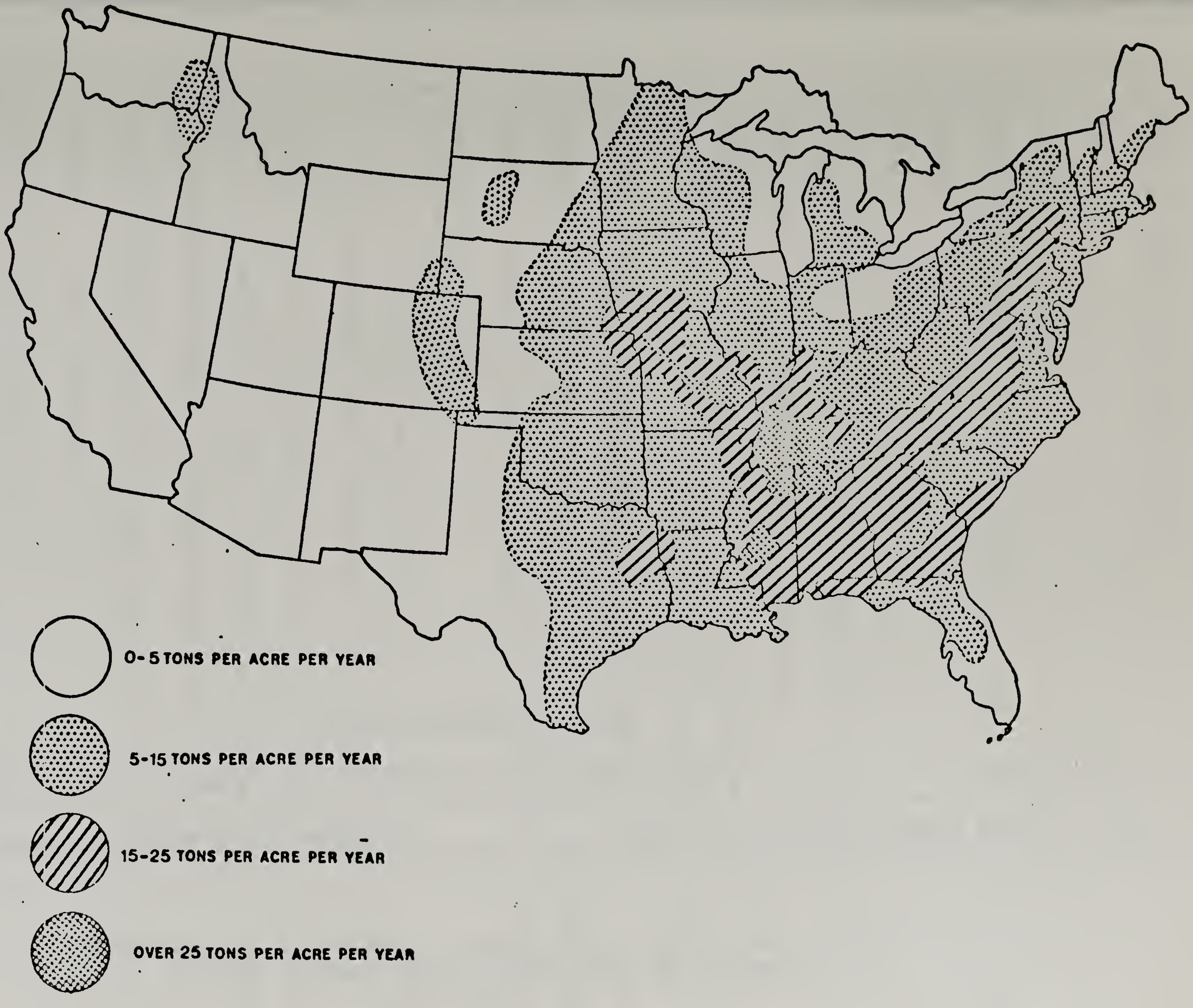
0-5 TONS PER ACRE PER YEAR
5-15 TONS PER ACRE PER YEAR
15-25 TONS PER ACRE PER YEAR
OVER 25 TONS PER ACRE PER YEAR

Figure III-35. SHEET AND RILL EROSION FROM WATER ON CROPLAND, WATER RESOURCES REGIONS 1-18, 1975

Source: USDA, Soil Conservation Service

Table III - 78
SUMMARY OF SHEET EROSION FROM CROPLAND BY REGIONS HARVESTED AND FROM FOREST - RANGE LANDS - 1975, 1985, 2000

Region	EROSION FROM CROPLAND HARVESTED			EROSION FROM FOREST--RANGE LANDS		
	1975	1985*	2000*	1975 -2000		
			(Tons per Acre per Year)			
New England	7	3	1	0.2		
Mid-Atlantic	14	6	3	0.5		
South Atlantic-Gulf	18	7	6	0.3		
Great Lakes	5	2	2	0.2		
Ohio	9	4	3	0.4		
Tennessee	19	5	4	0.3		
Upper Mississippi	10	5	4	0.6		
Lower Mississippi	23	12	6	0.3		
Souris-Red Rainy	2	1	1	0.6		
Missouri	7	4	3	1.5		
Arkansas-White-Red	6	3	2	1.0		
Texas-Gulf	7	5	3	0.7		
Rio Grande	2	3	3	0.9		
Upper Colorado	2	3	3	2.8		
Lower Colorado	2	1	1	2.0		
Great Basin	2	2	2	4.1		
Pacific Northwest	2	4	4	1.2		
California	1	1	1	2.6		
Alaska	-	-	-	-		
Hawaii	-	-	-	-		
Caribbean	-	-	-	-		
Total, Regions 1-18	9	4	3	0.9		
Total, Regions 1-21	-	-	-	-		

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* Assumes application of sound conservation measures.

Pasture, Range, and Forest Lands

Careful management of pasture minimizes sheet and rill erosion and effectively reduces sediment transport. Native grazing land or range prevalent in the Great Plains and Western range generally have lower erosion rates than cropland because rainfall is sparse and vegetative cover exists for the entire year. But range lands are subject to heavy runoff and erosion during sudden thunderstorms. Wind erosion is a threat on some denuded rangelands of the Plains. Erosion on pasture and range lands is increased by improper management of livestock grazing and periodic cultivation of marginal land. The magnitude of the erosion problem is shown by the grazing of half of all forest and range lands nationally and the exploitative grazing of 18 percent of such lands in the East (Table III-79).

Well managed forests provide the effective protection against sheet and rill erosion and sediment transport. Their dense, tree-leaf canopy, understory vegetation, deep root system, and ground litter prevents rapid runoff of rainfall and major soil movements in forests. The forest's natural protection against erosion is broken when trees are removed too fast when roads or skid trails are built and when understory litter is removed or disturbed.

Estimates of erosion rates from forests generally have been on too small a scale to establish general relationships between certain practices,

Table III-79
FOREST AND RANGELANDS SUBJECT TO EROSION FROM GRAZING AND EXPLOITATIVE GRAZING

Ecogroup	Area (million acres)	Grazed (million acres)	Grazed Exploitatively
Eastern Forests	393.5	159.9	72.4
Western Forests	1,606.6	97.2	2.2
Western Range	418.6	360.8	.9
Grat Plains	228.9	217.1	0
Alaska	351.2	19.0	0
Hawaii	2.9	1.2	0
Total	1,555.7	855.2	85.6

Source: U.S. Forest Service, USDA Forest Resources Report No. 21

such as clearcutting and sediment production. The experimental results vary greatly. However, estimates made for this Assessment indicate that soil losses from forest rangelands average nearly one ton per acre per year with the highest rate occurring in the Great Basins -- over 4 tons per acre per year (Table III-78).

Urban Areas and Construction Sites

Urbanization and highway construction generally increase erosion from the levels associated with the previous land use. The surface is destroyed, vegetation is removed, and the soil structure is destabilized by massive earth moving equipment. Gentler slopes may be replaced by steep ones.

Some studies of small sites in the eastern United States indicate that urban construction activity may increase erosion soil losses by as much as 5,000 times over the previous condition. After the construction has been completed the overall sediment yield from the urban sites tends to drop. Studies made in Maryland and Virginia* indicate that an average of 40-50 tons of sediment per acre per year can be expected during urban development when the soil surface is unvegetated and subject to constant reworking.

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* U.S. Geological Survey, "Sediment Movement in an Area of Suburban Highway Construction," Scott Run Basin, Fairfax County, Virginia, 1961-1964, Washington, D.C., 1969. Vice, Raymond B., et al. Erosion from Suburban Highway Construction Proceedings American Society for Civil Engineering, Vol. 94, Jan., 1968. Yorke, Thomas H., and Davis, William J. - Effects of Urbanization on Suburban Transport in Bel Creek Basin, Maryland. U.S. Geological Survey paper 750-B, 1971.

Urban development usually leads to a substantial increase in the amount and peak rate of runoff from the affected area. Such peak outflow areas often degrade the adjacent channels were the resulting bank erosion becomes a source of sediment for many years.

Surface Mines

Surface mines can be important sources of sediment from areas being cleared, grubbed, and scalped; roadways; spoil piles; areas of active mining; and areas being reclaimed.

Strip mining of coal is projected to increase substantially in the northern Great Plains and Rocky Mountain areas with attendant increases in erosion in these areas and sediment loads downstream (Figure III-36). In 1940 less than 10 percent of U.S. coal production came from surface mining. By 1972 strip mining accounted for 49 percent. Projections for the remainder of the century indicate that over 50 percent of U.S. coal production will be surface mined. The total land area disturbed by surface mining is estimated at about 4.5 million acres.

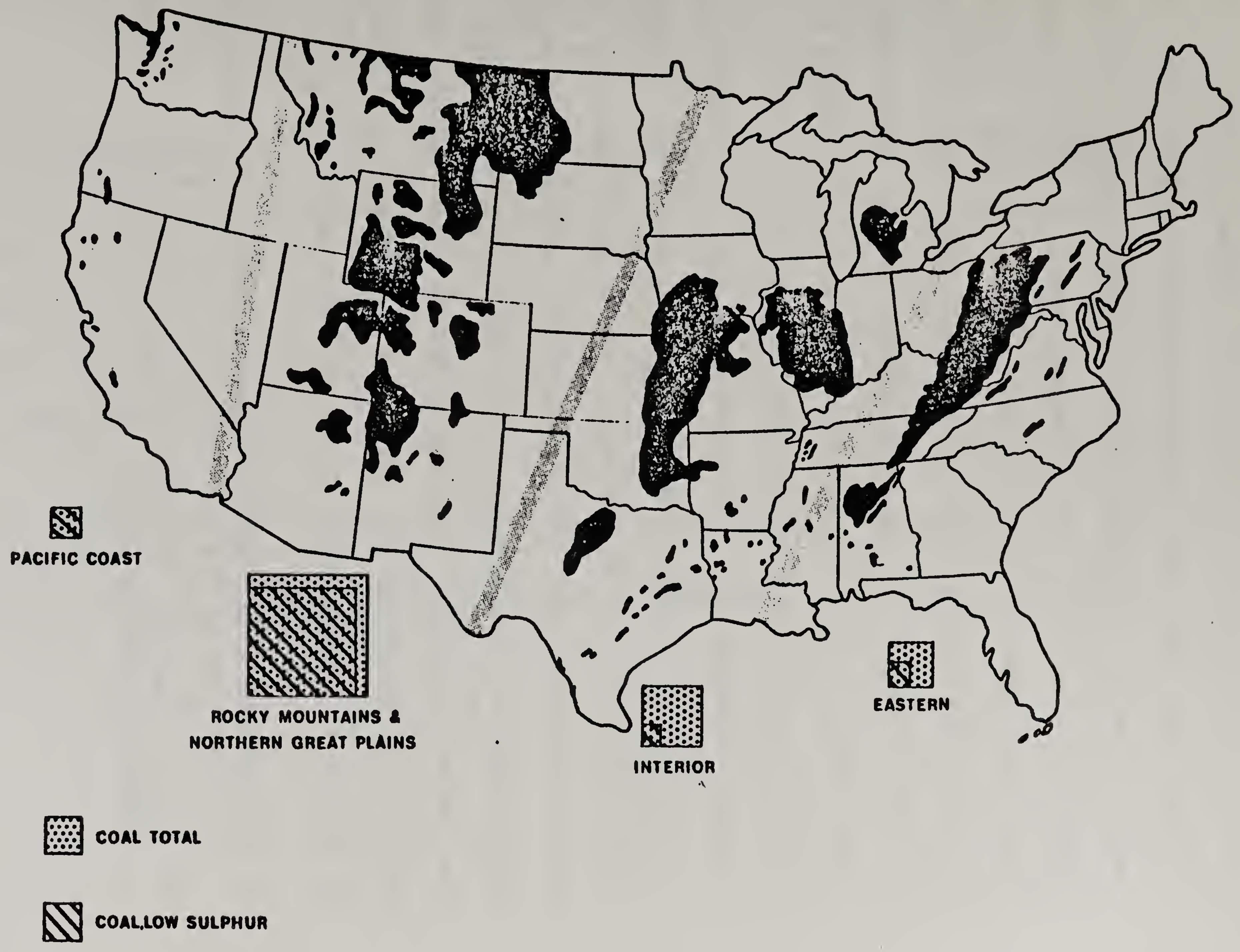
PACIFIC COAST
ROCKY MOUNTAINS & NORTHERN GREAT PLAINS
INTERIOR
EASTERN
COAL TOTAL
COAL,LOW SULPHUR

Figure III-36 -- LOCATION OF COAL RESERVES BY REGION OF THE CONTERMINOUS UNITED STATES

Source: U.S. Geological Survey

General methods for predicting the erosion rate from surface mined areas are not available. A study of the influence of strip mining on the hydrologic environment including sedimentation (on Beaver Creek Basin in Kentucky) concluded that spoil banks resulting from strip mining and prospecting are the greatest source of eroded materials. From 1958 to 1966 the average annual soil loss by sheet erosion was about 60 cubic yards per acre on the spoil banks. Where the outer slope was rilled and partly terraced the average annual loss was less than 15 cubic yards per acre. On the other hand, in an area drained by a large gully the annual rate of erosion was 159 cubic yards per acre. The sediment concentration in the receiving stream increased from 550 to 30,000 parts per million, and the annual sediment yield increased due to strip mining from 25 tons per square mile to 1,900 tons per square mile over the affected area. The average annual sediment yield from the spoil banks was about 27,000 tons per square mile.* Reclamation costs for surface mining may range over $5,000 per acre. Documented costs in Montana were $3,807 per acre (Table III-80); these costs would add only an average of about 10 cents to the cost of a ton of coal.**

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* U.S. Environmental Protection Agency, Erosion and Sediment Control: Surface Mining in the Eastern U.S.

** Atwood, Genevieve, "The Strip-mining of Western Coal," Scientific American, December, 1975.

Table III-80
PROJECTED COSTS OF RECLAIMING AN ACRE OF LAND IN MONTANA TO ITS PAST GRAZING VALUE WITH A UNIFORM TOPSOIL OF FOUR INCHES WHERE SPOIL SLOPES ARE 10 PERCENT GRADE

Reclamation Component	Incremental Cost Per Acre	Percent of Total Cost
Recontouring	$2,947	77.4
Topsoiling	612	16.1
Revegetation	122	3.2
Management and other	126	3.3
Total	$3,807	100.0

Source: Watts, M.J., Staff Paper 75-24, Department of Economics, Montana State University, cited in Ecology consultants, Inc.

Channels and Streambanks

In most forest and range country, and in areas with less than 20 inches of precipitation annually, channel-type erosion (including gully, streambank, etc.) generally produces the greater part of the sediment. In primarily agricultural watersheds with more than 20 inches of precipitation, the major source is generally sheet erosion.

Streambank erosion is dominant in semi-arid and arid areas and in the mountainous areas of the Pacific Coast regions. In the north coast watersheds of California and the Williamette Basin of western Oregon, the sediment contribution from streambank erosion is greater than from all other sources combined.

Out of an estimated 3.5 million miles of streams (7 million bank-miles) a total of approximately 8 percent, or 549,000 bank-miles, is currently undergoing erosion to some degree. Of this about 68 percent occurs west of the main stem of the Mississippi River (Figure III-37).

The most visible problem arising from bank erosion is the loss of land that occurs at the concave bank or when the stream cuts a new channel. The exchange usually results in a net economic loss because the "new" land is of uncompacted, generally coarse soil and lower in elevation. Rarely is it immediately as valuable or productive as the

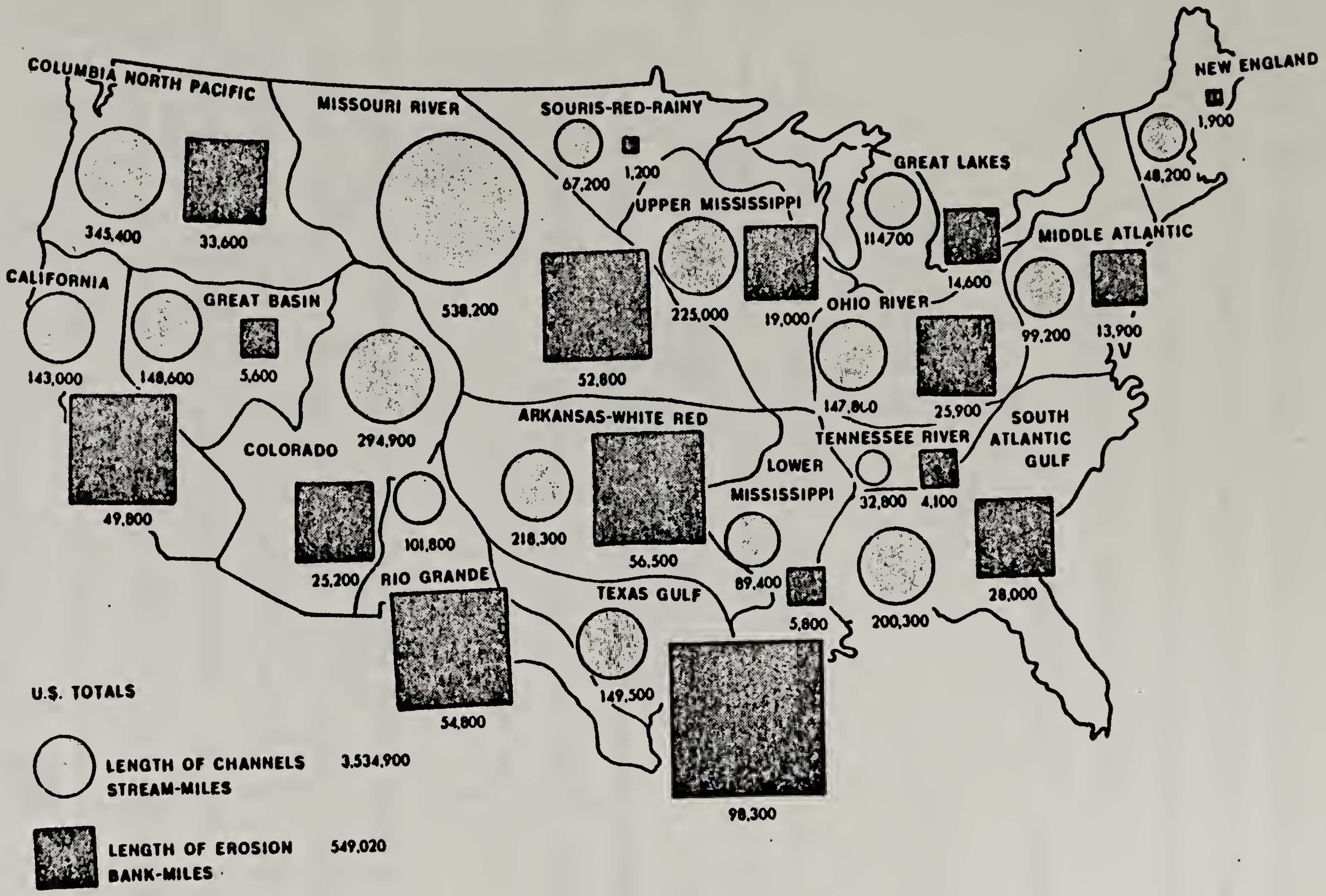
COLUMBIA NORTH PACIFIC
345,400
33,600
MISSOURI RIVER
538,200
52,800
SOURIS-RED-RAINY
67,200
1,200
UPPER MISSISSIPPI
225,000
19,000
GREAT LAKES
114700
14,600
NEW ENGLAND
1,900
48,200
MIDDLE ATLANTIC
99,200
13,900
CALIFORNIA
143,000
49,800
GREAT BASIN
148,600
5,600
COLORADO
294,900
25,200
RIO GRANDE
101,800
54,800
ARKANSAS-WHITE RED
218,300
56,500
TEXAS GULF
149,500
98,300
OHIO RIVER
147,800
25,900
TENNESSEE RIVER
32,800
4,100
LOWER MISSISSIPPI
89,400
5,800
SOUTH ATLANTIC GULF
200,300
28,000
U.S. TOTALS
LENGTH OF CHANNELS STREAM-MILES 3,534,900
LENGTH OF EROSION BANK-MILES 549,020

Figure III- 37-- STREAMBANK EROSION BY WATER RESOURCES REGIONS, 1969

Source: U.S. Army Corps of Engineers

land that was eroded. In addition, costly resurvey and litigation may be necessary to settle disputes that arise. With few exceptions, eroded banks are unsightly and tend to reduce environmental quality overall. The Corps of Engineers estimate total damages from streambank erosion to be in the range of $90 million annually*. Based on methods currently in use, acceptable streambank erosion control would cost about $420 million annually (Figure III-38).

Shorelines

The coastal zone is a uniquely valuable national asset. Nearly half of our population lives within 50 miles of the oceans or Great Lakes. The heaviest population of fish in the sea, and essentially all marine vegetation, are concentrated in the coastal zone. In the past 10 years, 90 percent of the national population growth has occurred in 30 coastal states.

About 2,700 miles of shoreline is suffering from critical rates of erosion (Table III-81 and Figure III-39). The major coastal areas located in the North Atlantic Region and the South Atlantic-Gulf Region have critical erosion problems directly related to the extensive shoreline development which may be threatened by storm wave erosion of the shoreline. Probably the most important effect of shoreline erosion is the threat to

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*USACE, "Streambank Study"

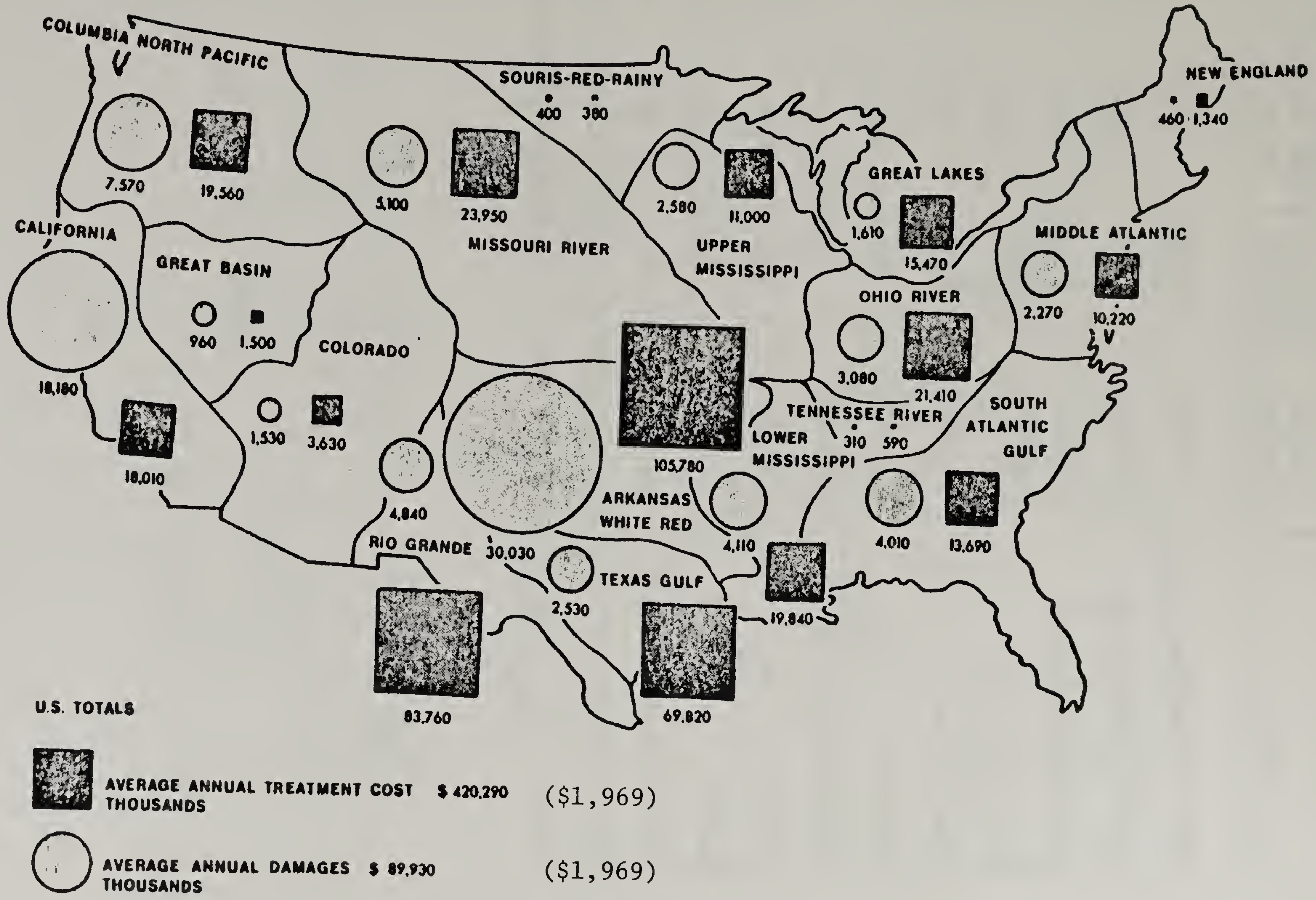
COLUMBIA NORTH PACIFIC
7,570
19,560
SOURIS-RED-RAINY
400
380
NEW ENGLAND
460
1,340
5,100
23,950
MISSOURI RIVER
2,580
11,000
UPPER MISSISSIPPI
GREAT LAKES
1,610
15,470
MIDDLE ATLANTIC
2,270
10,220
CALIFORNIA
18,180
18,010
GREAT BASIN
960
1,500
COLORADO
1,530
3,630
OHIO RIVER
3,080
21,410
105,780
TENNESSEE RIVER
310
590
LOWER MISSISSIPPI
SOUTH ATLANTIC GULF
4,010
13,690
4,840
RIO GRANDE
30,030
ARKANSAS WHITE RED
4,110
19,840
TEXAS GULF
2,530
83,760
69,820
U.S. TOTALS
AVERAGE ANNUAL TREATMENT COST $ 420,290 THOUSANDS
($1,969)
AVERAGE ANNUAL DAMAGES $ 89,930 THOUSANDS
($1,969)

Figure III-38 -- DAMAGES FROM STREAMBANK EROSION AND TREATMENT COSTS BY WATER RESOURCES REGIONS,1969

Source: U.S. Army Corps of Engineers

Table III-81

SEVERITY AND EXTENT OF SHORE EROSION BY WATER RESOURCES REGIONS

Region	Total Shoreline	Erosion Rates		
		Critical Erosion	Non-Critical Erosion	Non-Eroding
			(miles)	
North Atlantic	8,620	1,090	6,370	1,160
South Atlantic-Gulf	14,620	980	1,840	11,800
Lower Mississippi	1,940	30	1,550	360
Texas-Gulf	2,500	100	260	2,140
Great Lakes	3,680	220	1,040	2,420
California	1,810	80	1,470	260
North Pacific	2,840	70	190	2,580
Alaska	47,300	100	5,000	42,200
Hawaii	930	30	80	820
Total, Regions 1-18	84,240	2,700	17,800	63,740

Source: U.S. Army Corps of Engineers, The National Shoreline Study (August 1971)

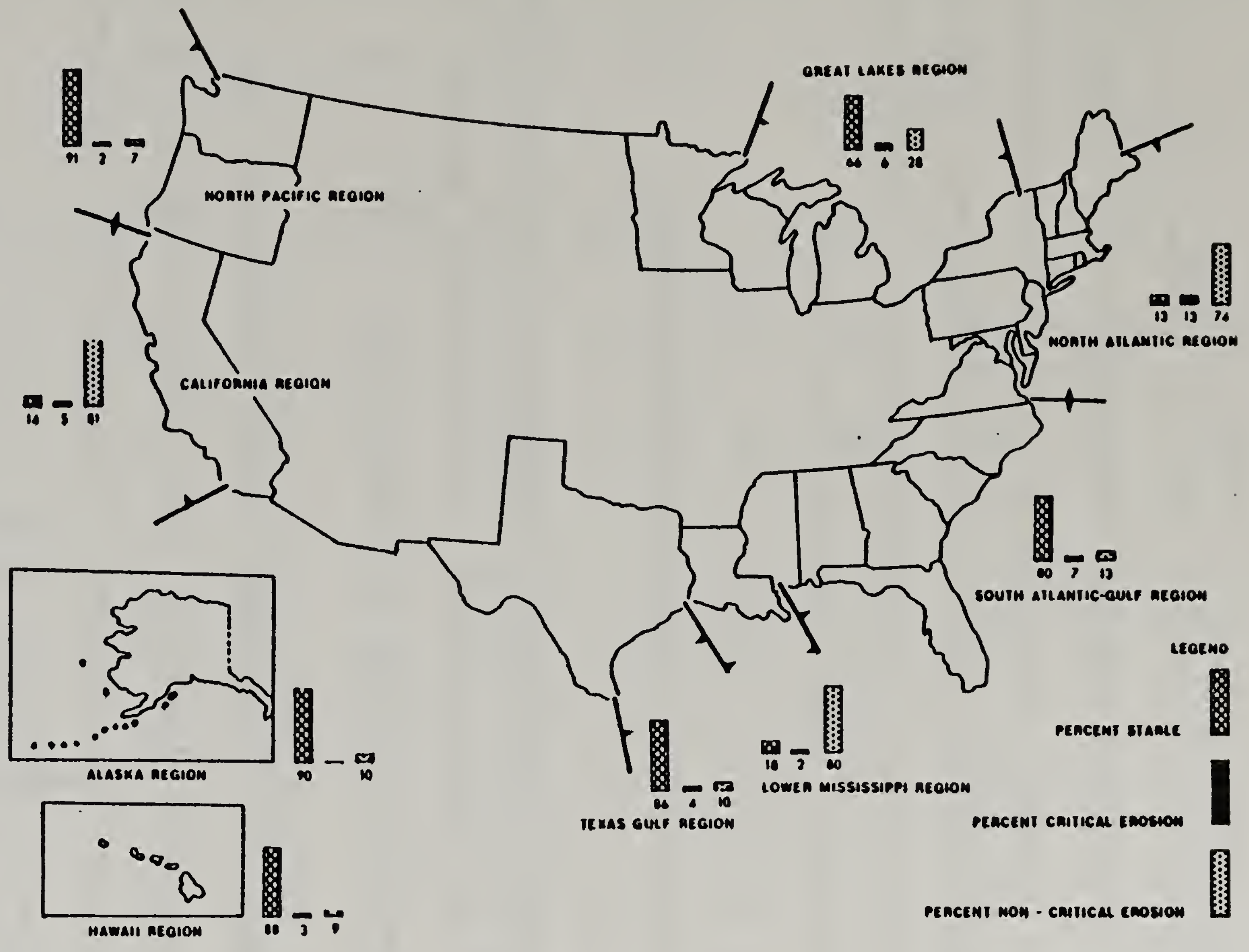
GREAT LAKES REGION
66 6 28
NORTH PACIFIC REGION
91 2 7
CALIFORNIA REGION
14 5 81
NORTH ATLANTIC REGION
13 13 74
SOUTH ATLANTIC-GULF REGION
80 7 13
LOWER MISSISSIPPI REGION
18 2 80
TEXAS GULF REGION
86 4 10
ALASKA REGION
90 — 10
HAWAII REGION
88 3 9
LEGEND
PERCENT STABLE
PERCENT CRITICAL EROSION
PERCENT NON - CRITICAL EROSION

Figure III-39-- DEGREE OF SHORELINE EROSION BY WATER RESOURCES REGIONS

Source: U.S. Army Corps of Engineers

beaches used for recreation. There are a number of special erosion problems meriting attention. One is the effect of inlets which trap sand in littoral transport and thereby deprive downdrift beaches, especially the productive barrier beaches.

Nationally, it would cost nearly two billion dollars to halt erosion on the 2,700 miles of shoreline undergoing critical erosion (Table III-82). This includes $1.8 billion in structures and other capital costs plus about $73 million annually for beach nourishment. More detailed study may be needed to decide where treatment is justified by the potential property owners and by users of beaches.

Options for Controlling Erosion and Sedimentation

The basic techniques and technologies for controlling erosion and sediment are simple in concept but complicated to implement. "The control techniques fall into three broad categories:

- proper land use management, based on soil resource data and conservation planning to select land for cultivation or other activities that is capable of supporting the planned use without excessive erosion;

Table III-82
PRIORITIES FOR SHORE EROSION TREATMENT AND ESTIMATED COSTS [1/]

	I		II		III		IV		V	
Region	Miles	$	Miles	$	Miles	$	Miles	$	Miles	$
Mid-Atlantic	130	180 (4)	442	350 (10)	248	220 (7)	274	270 (12)	1,094	1,020 (33)
South Atlantic Gulf	0	0 (0)	356	160 (5)	334	70 (3)	291	40 (2)	981	270 (10)
Lower Mississippi	0	0 (0)	29	10 (*)	0	0 (0)	0	0 (0)	29	10 (*)
Texas-Gulf	2	** (8)	13	10 (*)	47	40 (1)	33	20 (1)	95	70 (2)
Great Lakes	33	10 (1)	139	70 (1)	23	10 (*)	21	20 (*)	216	110 (2)
California	21	50 (3)	23	40 (4)	23	30 (2)	14	30 (2)	81	150 (11)
Pacific Northwest	0	0 (0)	16	10 (1)	3	10 (*)	54	40 (12)	73	50 (13)
Alaska	0	0 (0)	0	0 (0)	0	0 (0)	95	100 (0)	95	100 (0)
Hawaii	4	(*)	12	10 (1)	13	10 (1)	2	** (*)	31	20 (2)
Total, Regions 1-21	190	240 (8)	1,030	660 (22)	691	390 (14)	784	520 (29)	2,695	1,800 (73)

* Less than $1/2 million
** Less than $5 million

[1/] at 1970 prices. Estimates are preliminary and only indications of probable costs. Figures in parentheses are estimated additional average annual beach nourishment costs.

- land treatment, which involves such measures as minimum tillage and other conservation practices on agricultural land, minimum exposure of soil during urban and highway construction, and planting and preservation of vegetation on streambanks and mining spoil piles, for instance; and

- structural measures which control runoff and trap sediment in impoundments, revetments to protect streambanks, and jetties to help trap sand in littoral currents and thus provide renourishment for eroded beaches.

Controls or treatment must be related to the specific site, taking into account such factors as soil type, degree of slope, vegetative cover, climate, etc.

The lack of a coordinated national strategy for conservation reflects, in part, the complexity of the relationship between erosion reduction in a watershed and sediment load in its streams and rivers. It also reflects lack of public consciousness of the magnitude of the problem and the deficiencies of existing institutions to carry out greatly expanded programs. It is difficult to implement comprehensive conservation programs without strong National direction and even stronger local support and understanding of the sources and damages of erosion and sedimentation.

Cropland

Alternative future cases for the year 2000 were developed from a linear programming model prepared for the National Water Assessment. This model was used to estimate soil losses under various conditions of crop production and conservation measures. The future conditions can be compared to the exisiting situation (Table III-83). The study concludes that the National Future erosion reductions can be met while meeting National food and fiber production needs in the year 2000. But, achieving these goals would require major expansion in the application of conservation practices such as terracing, minimum tillage, and contour planting.

On the Western Plains and in the Great Lakes Region from 40 to 50 percent of the year's erosive rainfall normally occurs within 2 months after the average planting dates for corn, soybeans, and grain sorghum. In most of the Corn Belt and the eastern parts of Kansas, Oklahoma, and Texas the corresponding percentage is about 35 and in the Lower Mississippi Valley and Southeast, about 20 to 25. In the dryland grain-growing region of the Pacific Northwest about 80 to 90 percent of the year's water caused erosion occurs in the winter months when the soil frequently has little cover.

The basic strategy of soil conservation on cropland is a system of conservation cropping supported by cropping practices. On the best land, proper selection, timing, and rotation of crops is sufficient. No

Table III-83
EXISTING AND VARIOUS POTENTIAL EROSION SITUATIONS ON CROPLAND BY WATER RESOURCES REGIONS, 1975

Water Resource Regions	Existing Average Soil Losses (Tons/Acre)	Annual Soil Losses (Million Tons)			
		Existing Soil Losses With Present Farming Systems	Potential Soil Losses Without Conservation Treatment	Maximum Soil Losses Based on SCP Standards 2/	Reduction of Soil Losses Needed To Meet SCP Standards
New England	7	7	8	5	2
Mid-Atlantic	14	120	156	43	77
South Atlantic-Gulf	18	345	496	94	251
Great Lakes	5	107	114	107	0
Ohio	9	222	293	130	92
Tennessee	19	57	69	14	43
Upper Mississippi	10	515	604	269	246
Lower Mississippi	23	388	492	86	302
Souris-Red Rainy	2	39	51	39	0
Missouri Basin	7	577	908	402	175
Arkansas-White-Red	6	211	332	176	35
Texas-Gulf	7	158	211	109	49
Rio Grande	2	5	8	5	0
Upper Colorado	2	2	2	2	0
Lower Colorado	2	2	2	2	0
Great Basin	2	4	5	4	0
Pacific Northwest	2	36	43	36	0
California	1	5	6	5	0
Total, and Average Regions 1-18	9	2,800	3,800	1,528	1,272

1/ Source: USDA, Cropland Erosion by Water, 1977. The rates and total tons were computed in a model using nationally consistent procedures. The values footnoted may be different from some ASA's than local studies indicate.

2/ SCP refers to "sustained crop production standards" and is based on a maximum of 5 tons/acre/year.

row cropping is advisable on the poorest soils. The intensity of treatment depends on the relative condition of the soils in between these extremes.

The selection and combination of practices to fit the land and crop system is well covered in the literature. A combination of practices is needed to achieve various levels of erosion control is presented. It must be recognized, of course, that some of the practices that reduce soil loss and water runoff require increased investment and labor and may reduce crop yield and cash income. Where sediment yields still degrade the quality of receiving waters after all necessary erosion control measures are installed, specific sediment control measures can be installed. Filtering media or reservoirs that hold the water long enough for sediment to settle out are normally used for this purpose.

Pasture, Range, and Forest Lands

While cropland is the major source of sediment pasture, range, and forest must be considered in any strategy to control non-point sources of pollution. Many of these lands are coming under more intense use through expansion of man's commercial and recreational activities. Some have soils and terrain that are highly susceptible to erosion when soil cover is disturbed or removed.

Well maintained pasture generally has one of the lowest rates of sheet and rill erosion as compared to other land uses. Nevertheless, grazing or harvesting creates a need for:

- adjusting stocking rates to avoid overgrazing;
- rotating grazing to maintain a minimum vegetative cover;
- adding sufficient nitrogen and other fertilizers;
- fencing and placing water facilities to aid live stock distribution; and
- replanting as necessary to re-establish overgrazed pastures.

Forested lands generally have the lowest rates of soil loss. However, these lands too, must be managed properly to avoid excessive erosion and sedimentation. Some typical land treatment activities on forested lands include:

- Proper planning and design of forest roads and trails.
- Installation of erosion control measures following timber harvests and road building.

- Proper planning and design of heavily used recreation areas.

- Planned harvesting including approved silvicultural and regeneration activities.

- Protection against fire plus rehabilitation of burned areas.

Surface Mining

Five main principles underly any effective effort to control erosion and sedimentation in strip mining. They are:

- development of a reclamation plan to fit the site;

- minimum exposure of disturbed land, both as to area and time;

- erosion control as a first line of defense against off-site damage;

- sediment control as a second line of defense; and

- attention to a sound on-site maintenance program.

The implementation of each of these principles requires varying degrees of attention before, during and after mining operations.

Urban Areas and Construction Sites

About 2 million acres per year are presently being converted to urban land use. Planning is essential if the inevitable sediment increases are to be controlled. If good planning cannot eliminate potential sedimentation problems, then physical controls may be desirable. The physical controls should be installed as quickly as possible in construction areas. These may include sediment catch basins, sodded diversion terraces, sodded banks, mulching, and seeding.

Channels and Streambanks

The contribution of channel erosion to sediment yield is relatively small nationwide compared to sheet and rill erosion. Gully controls and stream, river, and floodplain channel stabilization works usually are not justified solely on the basis of reducing sediment load. The more usual purposes of bank protection are preservation of valuable land and structures along the channel, protection of floodplains from scour and sediment deposit, and alignment of the channel for navigation. Measures to control channel and streambank erosion and sedimentation include structures, revetments, upper bank protection (riprap, etc.), groins, and dredging.

Shorelines

Shore protection is most effective and economical when complete physiographic reaches are considered and proper attention is given to the effects of the protection on adjacent shores and on natural environments. Detailed studies of each site with careful consideration of alternative methods are essential.

Several control methods may be used for beach protection, but they are apt to vary in effectiveness, ecological effects, and erosion effects on adjacent shores. When conditions permit artificial fill with periodic nourishment to restore and preserve a beach is the preferred method; it is the natural method, is aesthetically pleasing, and permits a variety of recreational uses. In many areas vegetation may be used to reduce losses of sand from dunes or zoning and landuse controls may be imposed to reduce or control damage attributable to erosion. Physical structures such as groins, seawalls, revetments, and breakwaters are also available.

Conclusions

The chief factors mitigating against more extensive use and maintenance of erosion and sediment controls are:

- lack of incentive to make conservation investments on private land to create public benefits (such as cleaner water);

- incomplete knowledge of the relationship between erosion reduction in a watershed and sediment loads in streams and rivers;

- lack of institutional mechanisms for resolving conflicts between public interests and private ownership rights as it pertains to erosion and sediment;

- an incomplete evaluation of the impact of erosion on the productivity of our soil resources;

- the incomplete coordination of and inconsistencies and gaps between agriculture and environmental policies;

- lack of specifics in translating national policy for food production, protection of agricultural resource base, and water quality into specific, understandable, and reliable regional, state, county, and river basin erosion and sediment control accomplish ments;

- shortage of technical assistance and site specific strategies that provide information to the farmer on costs and expected benefits of conservation practices; and

- incompatibility of intensified production systems as monocultures with conservation management systems and of large machinery with traditional conservation practices.

Except for developing more information, the correction of these deficiencies is not simply a matter of doing more. Attitudes must be changed and conflicts resolved among competing interests for land and water.

The experience gained from the extensive spread of conservation practices on cropland could be used, however, in developing a national strategy. This experience indicates that to be successful a strategy should embrace (examples in parenthesis):

1. generating new information (erosion and sediment yield ratios);

2. setting objectives that reflect current goals (relating sediment tolerance levels at different stream locations to particular water uses at those locations);

3. implementing erosion and sediment control plans that utilize current technology (action on prioritized problem areas and sources);

    a. designing an aggressive system of incentives and disincentives (public sharing of the costs of conservation on private land and withdrawal of public subsidies for failure to implement conservation practices);
    b. continuing emphasis on technology transfer (technical assistance and demonstration projects);
    c. strengthening institutional arrangements (land use regulation that exert pressure on land users who refuse to control land erosion voluntarily or in response to incentives); and

4. monitoring land erosion rates and sediment delivered to the receiving waters and adjusting action plans (comparison of measured soil losses and sediment loads with objectives).

A comprehensive national strategy also requires consideration of projections for the future of such factors as food demand, soil losses under different rates of croplant production, and sediment yields, with data broken down to the smallest feasible units. Comprehensive projections are not available relative to gross erosion and sediment yield. But a start has been made for projecting erosion and sediment control needs in the different land and water use classifications.

Information Needs

The past two decades have seen the development of the first sophisticated tool for predicting soil losses and the effectiveness of control measures on cropland. Using the Universal Soil Loss Equation, the Department of Agriculture has produced handbooks giving factors for most soils and conditions on agricultural lands east of the Rocky Mountains. But the input data (factors) are incomplete for use in the equation in other regions of the country.

Beyond such refinements, however, research must address fundamental issues such as the interrelationships of erosion and sedimentation. The movement of soil particles once dislodged is imperfectly tracked. Even within streams limited gaging gives only partial information on the relative contribution of sheet and channel erosion to sedimentation. Stream gages and reservoir sediment measurements need to be correlated. Measurements from urbanized, forest, and range watersheds are limited. There is a serious need for more information on sediment yield by smaller hydrologic units. More information is also needed on the loss of future soil productivity from erosion and the increases in production costs.

Incentives

Assuming a national interest in conservation, protection of the land base becomes a social as well as private responsibility. In the past, subsidies have generally been viewed as a special privilege to the group taking action to achieve a public goal. Another possibility is to couple incentives with disincentives -- i.e., penalize land users who allow soil losses that exceed specified levels. The traditional cost sharing incentive for conservation should be high enough to compensate the users for the social benefit but require a user contribution sufficient to recognize the contribution to near term income. It might be in the public interest to provide an income supplement during conversion from a cropping enterprise to a livestock forage or forestry operation, for land purchase and relocation, or for other conservation measures.

Technology Transfer

Some new technologies for erosion control are being developed or have become recently available. New types of machinery reduce the amount of tillage or soil disturbance for planting. New conservation management systems are being developed that utilize computers and other modern technology to provide farmers with a range of cropping, tillage, seeding, irrigation, fertilization, and other options. New techniques for forest management, such as balloon or helicopter logging, aerial seeding, and those for fire detection and suppression, will help reduce erosion from forest and rangelands. The costs and benefits of each can be quickly estimated and the landowner can select a total conservation strategy best suited to the land.

Technical assistance is needed in the selection of alternative conservation treatment systems and the application of the selected system. Trained people must present alternative systems that are compatible with modern machinery and methods and still meet the needs and desires of the user. In many cases, needed systems are more technically advanced and costly than previous installations. Demonstration projects could be used to encourage conservation, perfect new technologies, and verify erosion reduction potentials.

Institutional Arrangements

Environmentally destructive practices for the short term economic benefit of a society rarely change without institutional change. Although institutional changes involve political decisions beyond the scope of a technical assessment document, policymakers must understand which institutions foster beneficial practices and which serve to prolong wasteful land and water use practices if they wish to stimulate meaningful change.

Conservation districts at local levels are in existence covering nearly all areas needing erosion control. But many are unable to carry out effective erosion control programs. Some have limited authority and restrictive policies. Often the districts were organized for very limited purposes and they traditionally serve a particular clientele. It is difficult to implement conservation on a national basis without stronger national direction. Some states need enabling legislation for their local conservation districts to carry out an effective program. Any effective program will need trained personnel and substantial funding to achieve the objective of reducing erosion and sedimentation to an acceptable level.

Erosion and sedimentation by their nature, affect both public and private land and water users. Equitable arrangements are lacking for the public to share costs with the landowner to commensurate with mutal benefits. Where private ownership predominates, the successful control strategy probably will combine voluntary measures; incentives, improved management techniques, regulation and enforcement. Regardless of the land use context, the key element in conservation participation of the public revolves around conservation goals and designing a particular site-specific strategy to achieve them. A start has been made with the national cropland, forest, shoreline and streambanks studies. Rapidly eroding areas and areas contributing large amounts of sediment to receiving waters must be identified and given immediate attention. A high priority should be the initiation of a national erosion and sedimentation monitoring system.

Appendix A

Names of Regions and Aggregated Subregions

WATER RESOURCE REGIONS AND SUBREGIONS

REGION NUMBER	SUBREGION NUMBER	REGION / SUBREGION
01		NEW ENGLAND
	0101	Northern Maine
	0102	Saco-Merrimack
	0103	Massachusetts-Rhode Island Coastal
	0104	Housatonic-Thames
	0105	Connecticut River
	0106	Richelieu
02		MID-ATLANTIC
	0201	Upper Hudson
	0202	Lower Hudson-Long Island-North New Jersey
	0203	Delaware
	0204	Susquehanna
	0205	Upper and Lower Chesapeake
	0206	Potomac
03		SOUTH ATLANTIC-GULF
	0301	Roanoke-Cape Fear
	0302	Pee Dee-Edisto
	0303	Savannah-St Marys
	0304	St Johns-Suwannee
	0305	Southern Florida
	0306	Apalachicola
	0307	Alabama-Choctawhatchee
	0308	Mobil-Tombigbee
	0309	Pascagoula-Pearl
04		GREAT LAKES
	0401	Lake Superior
	0402	NW Lake Michigan
	0403	SW Lake Michigan
	0404	Eastern Lake Michigan
	0405	Lake Huron
	0406	St Clair-Western Lake Erie
	0407	Eastern Lake Erie
	0408	Lake Ontario
05		OHIO
	0501	Ohio Headwaters
	0502	Upper Ohio-Big Sandy
	0503	Muskingum-Scioto-Miami
	0504	Kanawha
	0505	Kentucky-Licking-Green-Ohio
	0506	Wabash
	0507	Cumberland
06		TENNESSEE
	0601	Upper Tennessee
	0602	Lower Tennessee
07		UPPER MISSISSIPPI
	0701	Mississippi Headwaters
	0702	Black-Root-Chippewa-Wisconsin
	0703	Rock-Mississippi-Des Moines
	0704	Salt-Sny-Illinois
	0705	Lower Upper Mississippi
08		LOWER MISSISSIPPI
	0801	Hatchie-Mississippi-St Francis
	0802	Yazoo-Mississippi-Ouachita
	0803	Mississippi Delta
09		SOURIS-RED-RAINY
	0901	Souris-Red-Rainy
10		MISSOURI
	1001	Missouri-Milk-Saskatchewan
	1002	Missouri-Marias
	1003	Missouri-Musselshell
	1004	Yellowstone
	1005	Western Dakotas
	1006	Eastern Dakotas

WATER RESOURCE REGIONS AND SUBREGIONS

REGION NUMBER	SUBREGION NUMBER	REGION /SUBREGION
	1007	North and South Platte
	1008	Niobrara-Platte-Loup
	1009	Middle Missouri
	1010	Kansas
	1011	Lower Missouri
11		ARKANSAS-WHITE-RED
	1101	Upper White
	1102	Upper Arkansas
	1103	Arkansas-Cimarron
	1104	Lower Arkansas
	1105	Canadian
	1106	Red-Washita
	1107	Red-Sulphur
12		TEXAS-GULF
	1201	Sabine-Neches
	1202	Trinity-Galveston Bay
	1203	Brazos
	1204	Colorado (Texas)
	1205	Nueces-Texas Coastal
13		RIO GRANDE
	1301	Rio Grande Headwaters
	1302	Middle Rio Grande
	1303	Rio Grande-Pecos
	1304	Upper Pecos
	1305	Lower Rio Grande
14		UPPER COLORADO
	1401	Green-White-Yampa
	1402	Colorado-Gunnison
	1403	Colorado-San Juan
15		LOWER COLORADO
	1501	Little Colorado
	1502	Lower Colorado Main Stem
	1503	Gila
16		GREAT BASIN
	1601	Bear-Great Salt Lake
	1602	Sevier Lake
	1603	Humboldt-Tonopah Desert
	1604	Central Lahontan
17		PACIFIC NORTHWEST
	1701	Clark Fork-Kootenai
	1702	Upper / Middle Columbia
	1703	Upper / Central Snake
	1704	Lower Snake
	1705	Coast-Lower Columbia
	1706	Puget Sound
	1707	Oregon Closed Basin
18		CALIFORNIA
	1801	Klamath-North Coastal
	1802	Sacramento-Lahontan
	1803	San Joaquin-Tulare
	1804	San Francisco Bay
	1805	Central California Coast
	1806	Southern California
	1807	Lahontan-South
19		ALASKA
	1901	Alaska
20		HAWAII
	2001	Hawaii County
	2002	Maui County
	2003	Honolulu County
	2004	Kauai County
21		CARIBBEAN
	2101	Puerto Rico
	2102	Virgin Islands

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